Master's Thesis
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Human Factors in Automated Processes

The use of Human Factors methods to chart and prevent operator difficulties on an early stage in a development project

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Abstract

In today's dynamic market the use of knowledge about Human Factors is becoming a competitive mean to drive development and enhance usability. This Master Thesis is an attempt to study how increased machine reliance will affect the usability of equipment at Tetra Pak and also how Human Factors methods can affect and improve the development of new products and processes.

The object of study is a new line of more automated equipment (Easy ITS) within the Pre-press department at Tetra Pak. Aspects regarding execution of tasks, what machines are used, who the users are and the context of use were investigated. The main purpose of this Master Thesis was to integrate the operators' working methods and preferences on an early stage in a development project. By using Human Factors methods, future difficulties and errors were identified and solutions delivered.

The existing production line worked as the base for predictive analyses of the Easy ITS process and numerous observations and interviews were executed in two factories, one in Lund and one in Limburg. The collected data was presented and analysed using task analyses and a human error investigation approach called Systematic Human Error Reduction and Prediction Approach (SHERPA). When comparing the issues resulting from existing Pre-press SHERPAs with those of the Easy ITS SHERPA, the number of critical issues was alike, but the characteristics of the issues have shifted and new difficulties have become more prominent.

A comparison of the different factories revealed that automation facilitates the execution of tasks, but also limits the possibility to use home-made solutions or work around procedures to facilitate a task. The analyses provided an error distribution among the different machines and demonstrated where critical tasks took place. The issues found in the existing work process in Lund are equally divided between ergonomic issues and issues caused by human error. After the implementation of Easy ITS, ergonomic issues will increase and errors linked to human error decrease. This is due to a larger proportion of heavy sleeve handling in Easy ITS and less critical tasks related to precision when mounting clichés manually. Identified possible issues are described together with consequences and recommendations on how to improve the different processes. The study also illustrates that if suggested solutions are implemented the criticality of the Easy ITS line is significantly reduced.

The results show that it is not enough to simply automate a process and expect the operators' working environment to improve and operator errors to diminish. An iterative process involving the users is vital also when developing more automated processes. The SHERPA technique used in this study was concluded to be too time-consuming and complex on the chosen level of detail. However, the task analysis was a very useful tool as it encourages developers to think about the process as a whole and creates a basic knowledge of the process under development. We strongly believe that Human Factors should be a part of the everyday development work in a company like Tetra Pak.

Keywords: Human Factors, automation, human-machine interaction, user-centred design, human error identification, manual handling, task analysis.

Preface

This Master Thesis, executed at the Department of Design Sciences at Lund Faculty of Engineering, is the final part of a Master in Mechanical Engineering with product development and human centred design as the main focus.

The Master Thesis was initiated by the Authors after a weeklong visit to the development project *Easy ITS* within the Pre-press department at Tetra Pak. Its purpose was born during the first visit and then grew and developed during a summer project within the same project team. It was conducted as an independent project within the Easy ITS project but the conclusions drawn from it hopefully provides additional feedback to the project. The work started in October 2010 and ended in April 2011.

This Master Thesis study would not have been possible without the open attitude from the Easy ITS team and our thesis supervisor at Tetra Pak *Laurent Leloup* who included us in many of the important developments of the project. We also wish to express our deepest gratitude to the *members of the Easy ITS team* who have continuously helped us understand the technology of the process and participated in many discussions. Special thanks to *Anders Kristensson* and *Leonard Müller* who always kept our spirits up.

We also want to express our sincere gratitude to:

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Anders Gustafson and *Jan Vangö*, as well as everyone else at the Engineering Tools department at Tetra Pak, for their continuous support and interest.

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Last but not least we would like to thank *Gerd Johansson*, our tutor at the department of Design Sciences at Lund Faculty of Engineering for taking us in and giving us valuable support throughout the study.

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Glossary

Many new terms are introduced throughout this master thesis. To facilitate reading, a list of abbreviations and a glossary are provided.

Abbreviations	
4M	Man, Machine, Material and Method
ACT	Automatic Cutting Table – used for cutting out clichés from large plate
AM	Autonomous Maintenance
B.E	Back Exposure
CFA	Customer folder archive
CSR	Customer Sales Representatives
D&E	Development & Engineering
Easy ITS	Alternative process of ITS but same principle
HEI	Human Error Identification
HEQ	Human Error Quantification
HMI	Human Machine Interface
HTA	Hierarchical task analysis
ITS	Indirect to sleeve, new machine line…
LF	Light Finishing
M.E.	Main Exposure
MR	Manufacturing report
NIOSH	National Institute of Occupational Safety and Health
P2	Tetra Pak order/production planning computer program
PP	Pre-press
RA	Risk Assessment

RSI	Repetitive Strain Injury
SHERPA	Systematic Human Error Reduction and Prediction Approach
TA	Task Analysis
UCD	User-centred design
WCM	World Class Manufacturing

Glossary	
Anthropometry	The measurements of the size and proportions of the human body
Cliché	Cut polymer plate with 3D relief
EE-target	Productivity measurement used in the Lund factory
Human Machine Interface	The user interface in a manufacturing or process control system
Microflex machine	Machine used when manually mounting clichés onto sleeves
Paternosterverk	Rotating shelf system
Plate	Large polymer sheet, material out of which clichés are created and cut out from.
Pre-press	Department responsible for producing clichés and mounting them onto sleeves.
Relief	Height difference resulting from shapes carved on a surface so as to stand out from the surrounding background
Sleeve	Large plastic cylinder that the clichés are mounted onto. Approximately 1600mm wide, diameter ≈ 400-800mm and constant inner diameter and can way up to approximately 25 kg.
User-centred design	Design with the user in focus throughout the development process.

A Introduction

In this chapter what inspired this Master Thesis is shortly described. The purpose is defined together with the questions that will be answered throughout the study and the analyses. The sub-goals that need to be fulfilled in order to answer the questions are divided into five deliverables, and the confines regarding the context and execution of the study are specified. Finally the structure of the report is outlined to give the reader an overview of what follows.

In the world today, with several strong economies, emerging markets are growing and new manufacturing companies are constantly advancing. To remain competitive, manufacturing companies need to be dynamic and improve in new ways. It is no longer enough to have a strong position as the market leader; companies also need to distinguish themselves in innovative ways. Furthermore, with new markets follow more diverse user groups with other preferences and limitations.

To meet user needs, have an efficient product development and produce safe solutions, the usability of the end product needs to be considered as a competitive mean to drive development. Adding to that equation is increased technological complexity and automation which also results in new demands on the usability of the system.

1. Background

Tetra Pak is the leading company in the world when it comes to providing food processing and packaging solutions. As full systems supplier Tetra Pak supplies complete integrated processing, packaging and distribution lines and also involve technicians in installation and staff training.

All Tetra Pak developments are driven by trying to be *Faster*, *Better* and *Cheaper***.** This means cutting the time to deliver solutions to customers in half, raising the total quality in the full value chain so that everyone who comes in contact with the product in anyway appreciates it, and finally reducing production costs. Recently Environment was added to these goals.

To do this it is important to get products and new machine solutions right from the beginning as providing rebuilding kits both takes a lot of time and is expensive for the company. One way to enhance the quality of the development cycle is to have an iterative process where the end users are involved throughout the process.

Today Tetra Pak works with continuous improvement and development projects with participants from different work organisations. The Easy ITS project within the Pre-press department, one of these development projects, is working to develop a new machine line that in the future will replace existing production in the Pre-press department. After spending a few weeks working within this project it became clear that the most emphasis was put on developing robust and efficient machine solutions and that the operators' working tasks and the human-machine interaction often was left out. Consequently

the purpose of this Master Thesis was developed with the main goal to identify and cover these gaps and involve the knowledge of the operators already on an early stage in the development work.

One of the cornerstones that this Master Thesis is built on is the importance of considering humans and machines as a unit and not, as a common comprehension today, as independent components. Instead of linking issues and requirements to only one of the two, the interaction between technology and humans needs to be considered. This is an approach that will be highlighted throughout this process and which has also strongly influenced the formulating of the Master Thesis purpose.

2. Aim and Purpose

As mentioned above it is important to consider the user of the system when as in this case developing a new machine line. Aspects regarding the execution of the tasks, what machines are used, who the users are and finally the context of use needs to be considered. Furthermore it is important to understand existing ways when evaluating a procedure and suggesting solutions for the future.

For that reason the purpose of this Master Thesis is to integrate the operators' working methods and preferences on an early stage in a development project. By using Human Factors methods future difficulties and errors will be identified and solutions delivered. Additionally the use of these types of methods in development work at Tetra Pak will be evaluated and a future approach will be suggested.

The three main questions to be answered in this Master Thesis are:

- *What will be the operator difficulties with the Easy ITS production line?*
- *How can these difficulties be mitigated or, if not possible, decreased?*
- *How can Human Factors methods be used in development work at Tetra Pak?*

3. Goals

To clearly define the outcome of this Master Thesis the end product has been divided into five deliverables, all necessary to be able to answer the questions and purpose stated above. The sub-goals are connected to each other and are interdependent on the execution of the previous ones.

The five deliverables are:

1. **Literature review** including both physical, cognitive and organisational ergonomics and how Tetra Pak works with development projects and improvement work today. Additionally methods for Human Factor analyses are outlined.

2. **Current situation analysis** focusing on the work situation in Pre-press today. Here the working steps will be described and investigated and a retrospective human error analysis constructed.

3. **Easy ITS analysis**. The new working steps will be described and investigated and a prospective human error analysis constructed. From the human error analysis the most critical and common issues will be delivered.

4. **Solutions to Easy ITS**. For the most critical issues found in Easy ITS in depth solutions will be presented.

5. **Method evaluation**. Finally the selected methods will be evaluated based on what they could deliver and their practicability for future work at Tetra Pak.

4. Confines

The Master Thesis will study the existing Pre-press production line and the machines under development in the Easy ITS project and hence the other parts of Tetra Pak's Packaging Material production are not covered in the study. However, when a task execution in Pre-press might have a negative impact on later production steps this is noted in the error analysis. Furthermore the study of how Tetra Pak works with improvement work is done generally and is not specific to the Pre-press department.

As mentioned above the study will focus on delivering solutions on issues identified in the gaps between the machine processing steps in the Easy ITS project. These activities will influence the areas of interest when studying the existing Pre-press line in the way that more focus will be put on activities between machine processing.

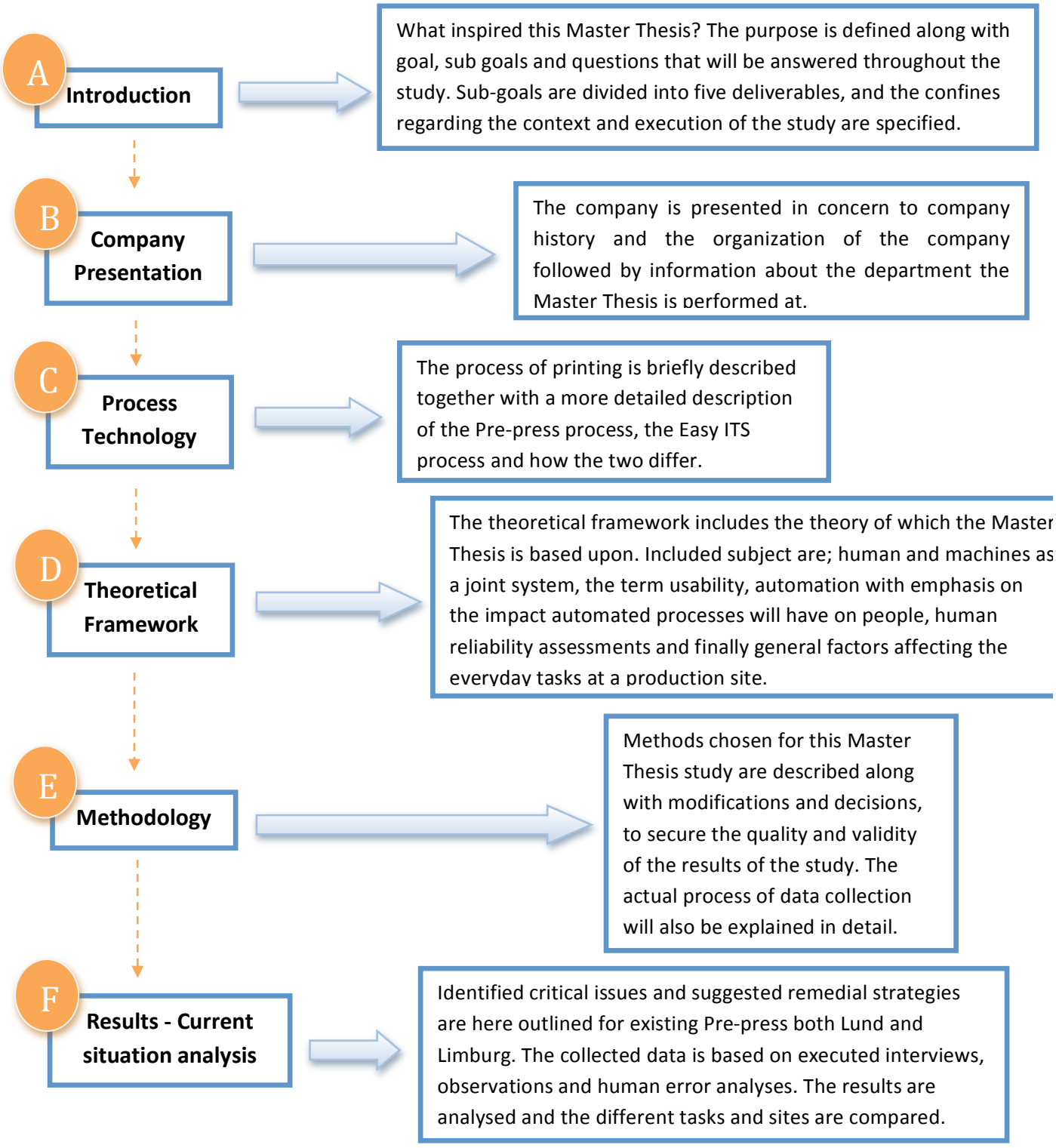
In the study an understanding of machine functionality is necessary but the technology of the machines is only described so that the operators' tasks can be understood sufficiently. The focus is on task execution and the machines are studied as means to perform the tasks.

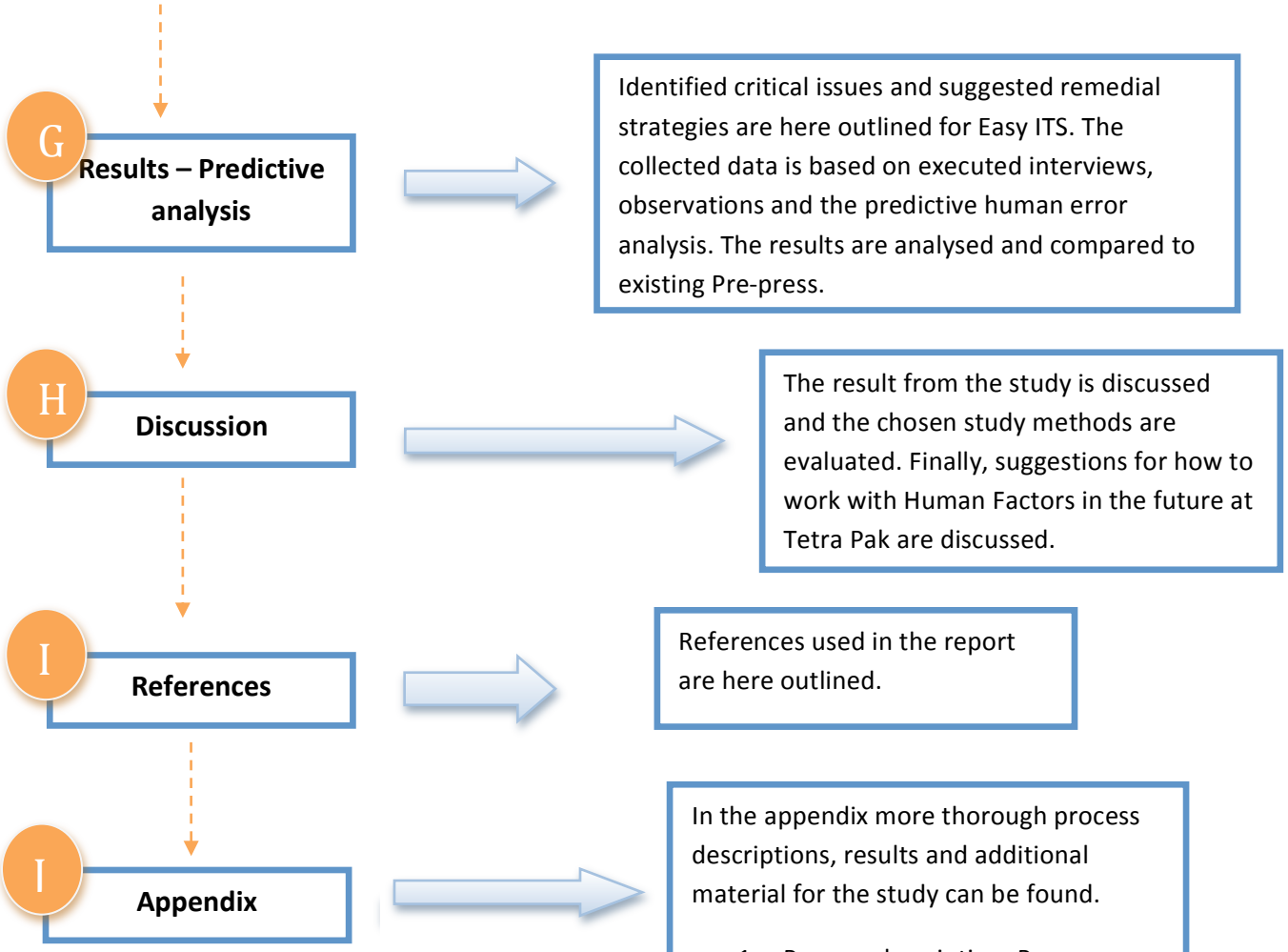
The Master Thesis study will be executed based on Human Factors methods and theories. Physical, cognitive and organisational ergonomics will be taken into consideration. To investigate the operators' working environment aspects regarding the execution of the tasks, the design of used machines, user characteristics and finally the context of use will be considered. Regulations and specific values concerning the work environment such as recommended temperature and illumination values will not be included in the report.

The detail to which solutions are given is dependent on rated criticality in the study, possibilities to affect machine or process design and of course the time limitations of this Master Thesis. If feasible, solutions will be virtually presented and if found more profitable shorter solutions this will be done instead. Shorter descriptions are done to be able to cover as many issues as possible. Recommendations of previous procedures will also be regarded as solutions delivered.

5. Report outline

In order to give the reader an overview of the report and its structure the different parts and their contents are summarised in the report outline below.




G
Results – Predictive analysis
Identified critical issues and suggested remedial strategies are here outlined for Easy ITS. The collected data is based on executed interviews, observations and the predictive human error analysis. The results are analysed and compared to existing Pre-press.
H
Discussion
The result from the study is discussed and the chosen study methods are evaluated. Finally, suggestions for how to work with Human Factors in the future at Tetra Pak are discussed.
I
References
References used in the report are here outlined.
I
Appendix
In the appendix more thorough process descriptions, results and additional material for the study can be found.
1. Process description: Pre-press
2. Process description: Easy ITS
3. In depth study: Sorting
4. In depth study: Manual Handling
5. Task Analyses
6. Interview material
7. SHERPAs

B Company presentation: Tetra Pak

In this part the company is presented in concern to history and the organization of the company followed by information about the department the Master Thesis is performed at.

Tetra Pak is a family owned company specialized in developing complete solutions for processing, packaging and distribution of food products. In 2009 the company produced packaging material and closures at 42 plants, employed 21,672 people and had a net sale amounting to 8,955 million Euros. Tetra Pak is not only the world leader in liquid food processing and packaging, but also processes and packages non liquid foods such as ice cream, cheese, fruit, vegetables and pet food. The company aims to offer a facilitated way of distributing products while preserving both nutritional values and taste. The products supplied by the company are divided into the following; Packages, processing equipment, filling machines, distribution equipment and service products (Tetra Pak Official Homepage, 2010).

1. Company History

The work with developing a new way to package milk started already 1943. Ideas of coating paper with plastic and sealing the package below the level of liquid served the basis for introducing a new way to distribute milk maintaining maximum hygiene. The following information concerning Tetra Pak company history is taken from Tetra Pak's Official Homepage (2010).

Tetra Pak was established in 1951 by Ruben Rausing and Erik Wallenberg in Lund, Sweden, as a subsidiary to Åkerlund & Rausing. The first Tetra Pak machine was delivered to Lund Dairy in September 1952 and by then attracted great attention. Following were deliveries to several other dairy centrals around the country. In 1965 Åkerlund & Rausing was sold and Ruben Rausing kept AB Tetra Pak under his own shield. Tetra Pak AB continued to grow and plants were started up all over the world, reaching for example Australia in 1974. In 1979 the first Tetra Brik Aseptic machine was delivered to the People´s Republic of China and by 1980 the total production of Tetra Pak packages exceeded 30 billion units.

In 1991 Tetra Pak joined with the local company Alfa-Laval, by then one of the world's largest suppliers of processing equipment and plants to the food industry, forming the Tetra Pak Alfa-Laval Group. Two years later the Tetra Laval Group was created. In 2003 the third member of Tetra Laval joined, namely Sidel, one of the world's leading companies in machinery for plastic bottles. Over the next few years the company expanded regularly, starting up plants all over the world, exceeding a total production capacity of 120 billion cartons in 2005. Thanks to acquisitions of other world leading competences such as Tebel MKT in 1995, and developing solutions such as re-closable caps in 2001, Tetra Pak continues to grow and maintain its position on the world market.

2. Company Structure

2.1. Tetra Laval Group

The following information concerning Tetra Laval company structure is taken from Tetra Laval's Official Homepage (2010). At the very top of the organisation is Tetra Laval Group that is the leading group for food processing and packaging equipment in the world. As a group Tetra Laval employ over 31,000 people and for 2009 they presented a net sale of 10,755 million Euros.

Tetra Laval Group consists of three independent groups, Tetra Pak, DeLaval and Sidel (see figure B.1). The independent groups each have their own operational management and report back to the Tetra Laval Group Board. Tetra Pak is the largest group producing a net sale of 8,955 mio Euros in 2009, more than 83% of Tetra Laval total sales.

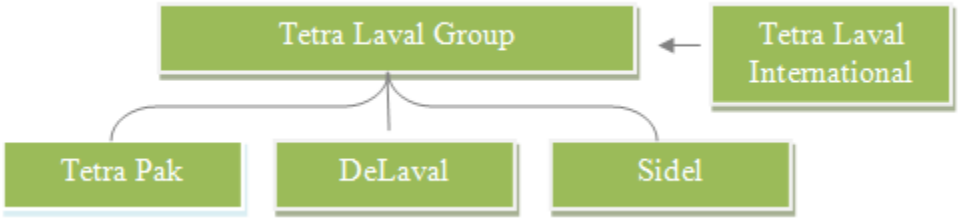


Figure B.1 Illustration of Tetra Laval Group main components

Tetra Laval International is another part of Tetra Laval Group that has the leading role in corporate governance, including proposing and ensuring compliance with reporting processes, executing acquisitions and disposals. Tetra Laval Group Board is responsible for the overall strategy and for controlling and supervising all business operations.

2.2. Tetra Pak

Tetra Pak Group as a company consists of two main businesses, Packaging and Processing solutions, see figure 2. The Master Thesis is performed at packaging solutions, within Development and Engineering and more specifically within Packaging Material. In figure B.2 below the organisation in relation to where the Master Thesis work belongs is shown. Packaging Material involves many departments, among them Converting within which Pre-press and Printing belongs. The Pre-press and Printing process team works with developing and also maintaining and improving specifications for the department. Their main goal is to make sure that all factories deliver good and uniform printing performance and results (Tetra Pak Official homepage, 2010).

The Master Thesis is performed within a development project that aims to improve the Pre-press process and therefore lies under the Pre-press department. This development project is called the Easy ITS project.

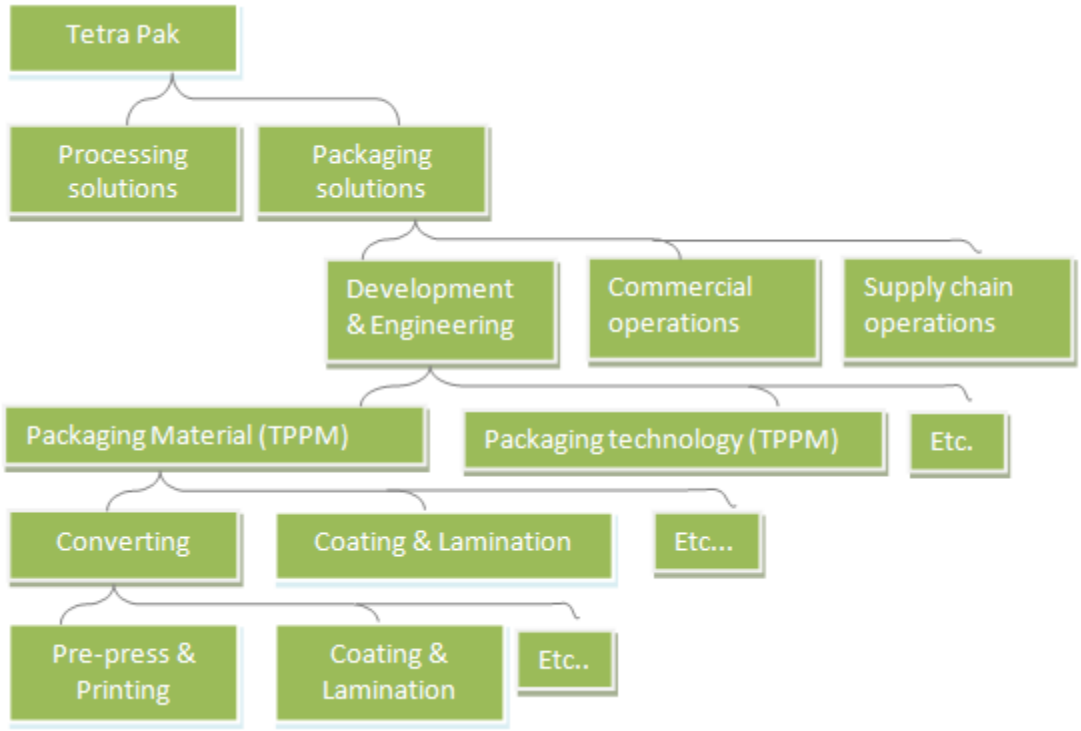


Figure B.2 Illustration of Tetra Pak organisation in relation to the Pre-press and Printing department

2.3. The Easy ITS project

The ITS project, *Indirect To Sleeve*, was initiated to introduce a new technology of mounting clichés onto sleeves by using a machine instead of manual mounting. Along its development process difficulties and requirement changes have steered the project in different directions and alternative processes have developed. By the time the Master Thesis is concluded the project has been given the name Easy ITS project. The process studied in the Easy ITS project is the one that the Master Thesis will be based on.

Easy ITS is developing a production process that will include both producing clichés and mounting them onto sleeves. First of all it will eliminate the need to manually mount clichés. Secondly the project has developed new equipment in cooperation with external suppliers. Many of the new machines combine several machine units used in Pre-press today and in that way makes the new process more automated than the existing one.

C Process Technology

In this chapter a brief description of the process of printing is given together with a more detailed description of the Pre-press process as it worked in Tetra Pak in 2010. Furthermore an explanation of how the existing Pre-press process differs from the new Easy ITS process that is introduced in the development project, in which the Master Thesis is performed.

1. Printing technology

1.1. Flexography

To create a print on their packages Tetra Pak uses a technique called Flexography which is one of the most common types of printing used in the packaging industry. In Flexography, flexible photopolymer printing plates, called clichés, are used. On the printing plate a positive mirrored image is created by 3D reliefs in a polymer material. The printing plates are then placed on sleeves, large cylinders that are used as printing rolls in the large printing machines also designed by Tetra Pak. How these plates are created and mounted will be described later in this section.

One of the benefits of using Flexography is the possibility to use a wide range of inks, which in turn gives the possibility to print on a variety of different materials. Also, the types of ink used in Flexography have relatively low viscosity enabling faster drying, which in turn results in faster production and lower costs (Devon International, 2011).

To print a coloured image Tetra Pak uses the CMYK-colour model which is a subtractive colour model, see figure C.1. The model is called subtractive because the ink subtracts the brightness of some colours from a white surface and in that way letting other colours show since white is in fact all colours given an equal amount of brightness. The ink reduces the light that would otherwise be reflected. CMYK is short for the colours cyan (C), magenta (M), yellow (Y) and a key colour (K), which is usually black (Steinhoff, 2009). In addition to these special colours, so called house colours are sometimes used. Coca cola-red is an example of a house colour that is specific for a company or print.

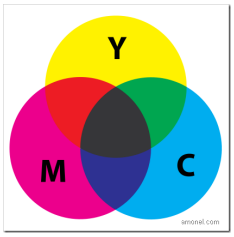


Figure C.1 CMYK colour model illustration

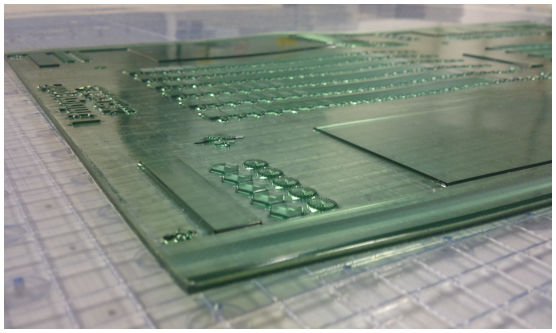
For the printing process at Tetra Pak, the standard is to use six colours, while seven colours is the maximum amount in the printing machines. To be able to add one colour seperately several sleeves are used. Each sleeve is covered with the décor corresponding to a certain colour. Pre-press is the part of the printing process where the photopolymer plates, also called clichés, are created and mounted to sleeves (Observations and Interviews).

In order to make full use of the printing equipment at all times, smaller orders sometimes need to be combined with others to fill out a large paper roll. Combinations like this are called co-prints and they

differ from single prints in the way that each lane on the sleeves may create a different print. After printing the lanes are separated and rolled onto smaller rolls to be sent separately to the corresponding customer (Observations and Interviews).

2. Cliché Making

Clichés are polymer plates with a 3D pattern on one side, see picture C.1. The pattern is created by many small dots on which ink will attach and then be transferred to the paper.



Picture C.1 A cliché ready for mounting

Initially the clichés were created using an analogue technique. As many technologies have converted to digital processes so have Pre-press' plate making process. The factory in Lund has already received equipment for a digital process and digital is also the technique that the new process line investigated in this Master Thesis is based on.

In a digital process each plate is prepared with a black top layer in which a positive mirrored image is created using a laser. The plate is first exposed from the back side, where there is no black layer, creating a so called floor, see figure C.2. This will secure the relief anchorage when the unexposed polymers together with the black layer later are removed.

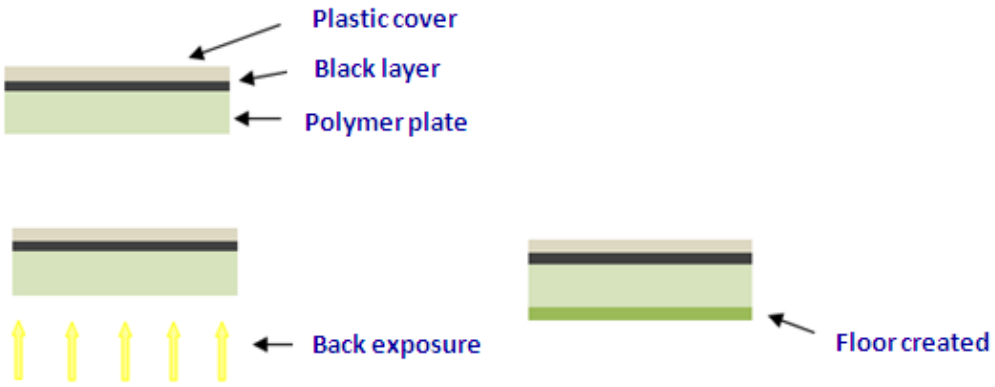


Figure C.2 Illustration of Cliché Making process, Back Exposure

After the floor is created the plate is placed in a digital Imager where parts of the black layer are removed, creating and image with the laser beam, see figure C.3.

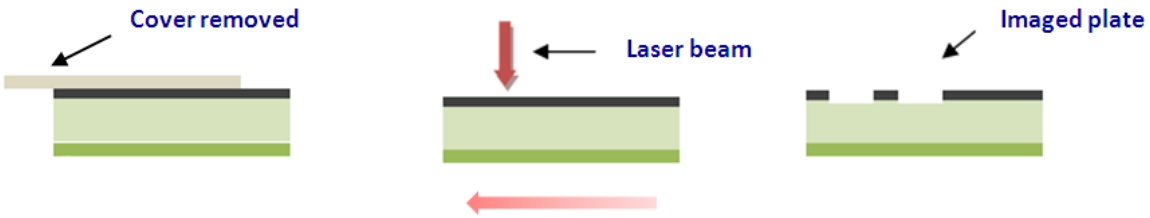


Figure C.3 Illustration of Cliché Making process, Imager

The surface is then exposed with light to harden the polymers and so called reliefs are created, see figure C.4. It is on these reliefs that are covered with ink that is then transferred to the printing object, here the paper.

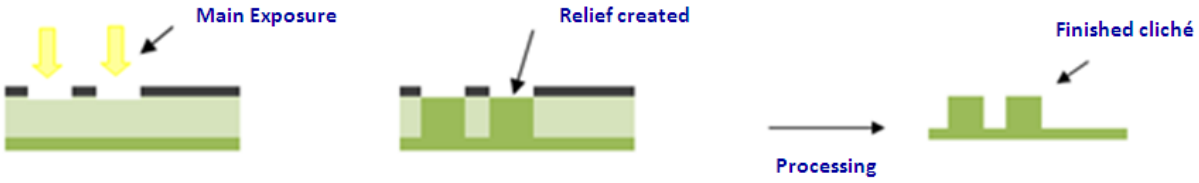


Figure C.4 Illustration of Cliché Making process, Main Exposure and Processor

In an analogue process there is no black layer on the plates, instead negative films are placed on top of a plate before they are exposed with light. This means the machine with the laser beam, called Imager, is not used. Instead films are placed on top of the plate and fixed in one place while the plate is exposed. The rest of the process is made in a similar way as the digital explained above.

Each large plate has room for several clichés. The layout of the clichés on each plate is done in a computer program for the digital process. For the analogue process this layout is planned by the operator when placing the films. After being processed the décor plates are cut out, arranged and placed in piles.

3. Cliché Mounting

In Cliché Mounting the clichés are sorted and mounted onto sleeves, long cylinders, see picture 2. Mounting clichés is in a way a craftsmanship as it to a large extent relies on operator skills, a steady hand and full concentration.

Picture C.2 Sleeve with mounted clichés

In many factories this is a bottleneck and not all employees are able to perform the activity which makes the task very labour dependent. Avoiding manual mounting is preferable both for improving accuracy in positioning of clichés but also when aiming to make the task of mounting clichés more time efficient.

To make the clichés stick to the sleeve, the sleeves are first covered with tape (turquoise layer under clichés in picture C.2). Tape can either be cut in pieces corresponding to the size of the clichés or mounted in larger pieces, for example three wide lanes mounted from a roll of tape directly onto the sleeve, see picture C.3.

Picture C.1 Operator mounting tape in a semiautomatic taping machine

The sleeves that the clichés are mounted onto have different diameters depending on the size of the décor. Sleeves can be of different materials depending on the printing technique. If hard sleeves are used it is common to use a somewhat compressive tape. There are also sleeves made up of a more compressive material which can be used with a thinner type of tape.

4. Equipment for Pre-press

4.1. Cliché Making

The main steps of the process of Cliché Making are shown in figure C.5 and described in the following text. The level of automation is illustrated by circles and squares that represent manual or machine based activities. As figure 8, shows Cliché Making includes several machine based activities mixed with two manual tasks of planning the digital layout of the large plate and also sorting the cut out clichés at the end of the process.

In Pre-press Lund two types of exposures units are used: a back exposure (B.E) and a main exposure (M.E). The back exposure, used to create the floor, requires less than a minute of exposing time. The main exposure takes several minutes for each exposure. Exposing takes place in an exposure unit, which is similar to a large light table with a lid, and both exposing types, mentioned above, can be done with the same machine as long as the exposure time is adjusted.

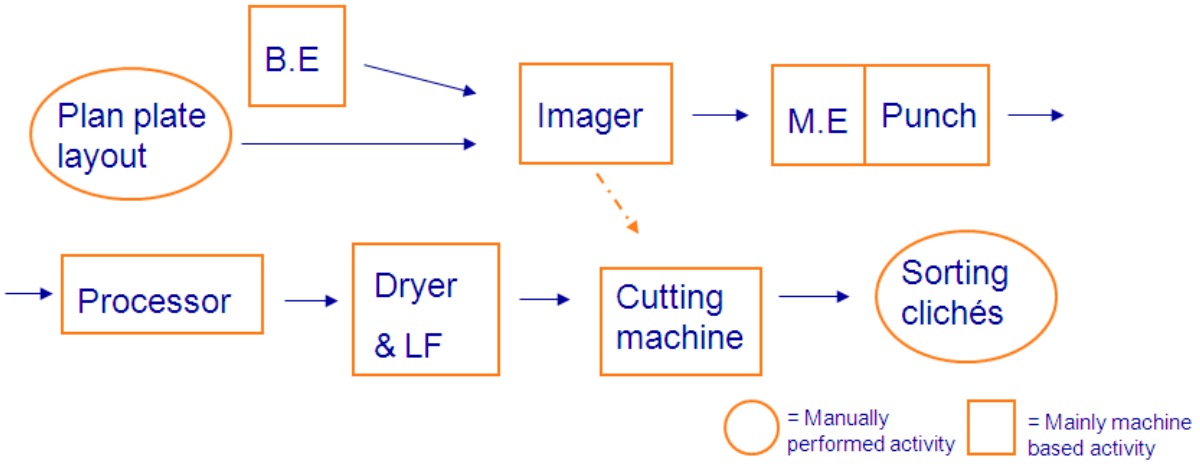


Figure C.5 Illustration of the Cliché Making process in Lund Factory including main steps and their level of automation

For creating the digital imaged plate an imager is used. The imager has a large drum onto which the plate is rolled. Inside the machine a laser moves from side to side as the drum rotates. For analogue processes this machine is not used, instead negative films are placed on top of the plate while it is exposed, held together by a vacuum cover.

For removing the remaining unhardened polymers the large plate is pulled through a processor where brushes and chemical solvent is used. To attach the plate to the processor holes are punched out on the plate already in the main exposure. After processing, the plate needs to dry off the solvent in a dryer and be exposed to UVA and UVC light to create a finishing layer, in a machine called the light finisher. When the plate is finished it is cut either automatically or manually into smaller plates called clichés. Each cliché contains a separate décor assigned a certain design and colour.

4.2. Cliché Mounting

The main steps of the Cliché Mounting process are illustrated in figure C.6 below and described in the following text. The figure illustrates that all tasks involved in Cliché Mounting are manual tasks, it also shows that it only consist of preparations for mounting and the actual mounting of clichés.

Before the clichés can be mounted they need to be sorted so that they are put in the correct order and that the correct print is given the corresponding colours in printing. Each sleeve needs to be prepared with tape before clichés can be mounted. Depending on the tape type the tape can either be mounted in the same machine as the clichés or on a separate tape mounting machine. Tape mounting machines are often semiautomatic, providing a fixed shaft and a roller removing unwanted air bubbles from under the tape. Positioning the tape is however still a manual task.

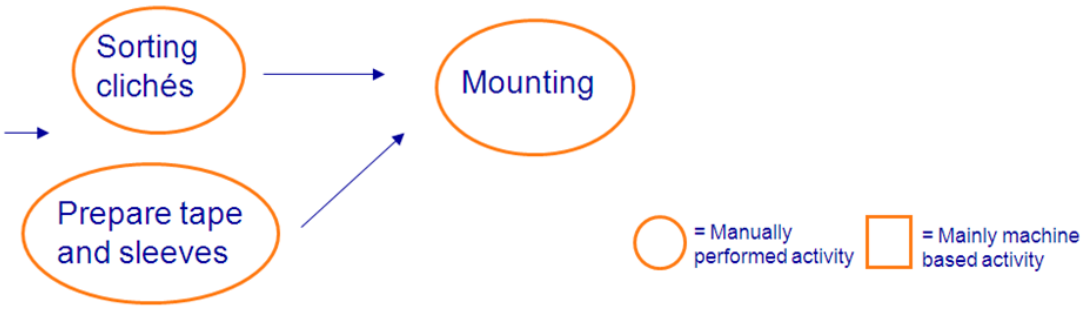


Figure C.6 Illustration of the Cliché Making process in Lund Factory including main steps and level of automation

Today a mounting machine called Microflex is used to provide aid for the operator when mounting. Each cliché is produced with microdots that are created in the Imager in correct relation to the décor. If these microdots are positioned correctly onto the sleeve, so is the print.

Two magnifying cameras help the operator position the microdots on the sleeve and the Microflex machine also makes sure the sleeve is positioned correctly in relation to the cameras. Depending on the sleeve type being mounted the machine automatically provides different stepping between each cliché to get a more even pressure in the printing machine.

Before the Microflex machine was introduced clichés were mounted manually, using mirrors for better accuracy. Prints were then tested before they were sent to printing to make sure they were positioned correctly. It would be safe to say that this method resulted in more mounting errors.

5. The Easy ITS process

The Easy ITS process combines several of the steps in Pre-press today. Figure C.7 shows the process briefly including the machines used and also the level of automation. The Easy ITS process is described more in depth in the appendix 2 (*Process description: Easy ITS*).

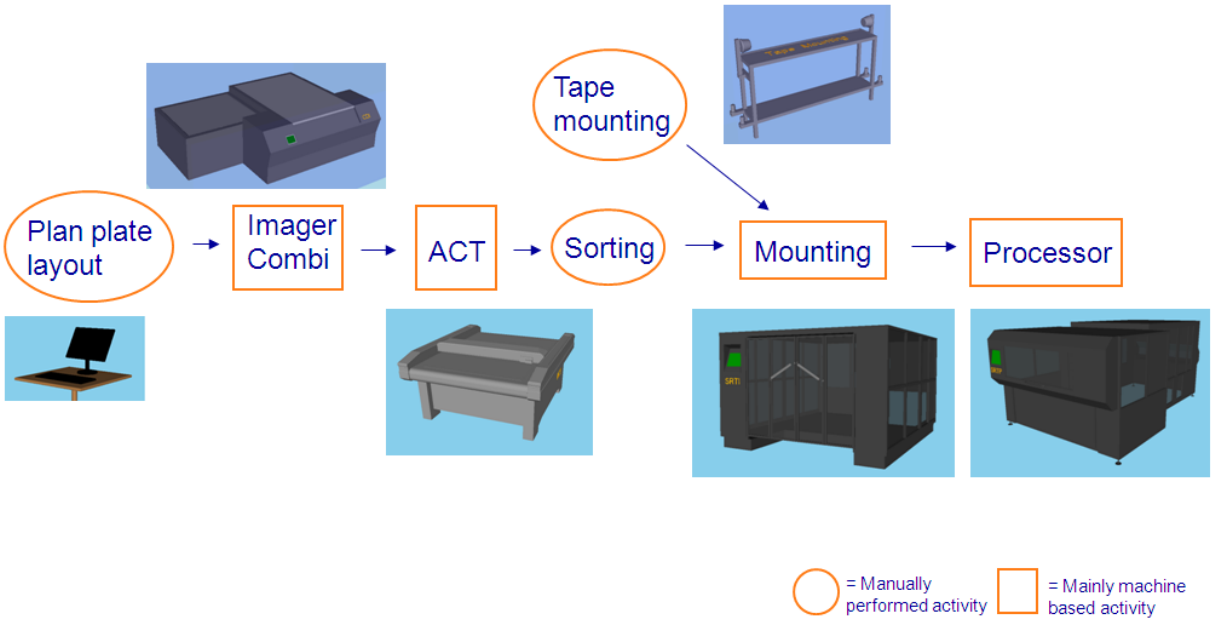


Figure C.7 Illustration of the Easy ITS process including main steps/units and level of automation

In order to produce the plate layout the same computer programs will be used in the Easy ITS line as in existing Pre-press.

In cooperation with a supplier, a machine called the Imager combi that combines digital imaging, main exposure and back exposure, has been developed to work with the new process. After the plate has gone through this machine it is placed on an automatic cutting machine where the initially made plate layout file is used to cut out the clichés from the large plate.

Parallel to this, sleeves will be prepared by tape mounting, which is performed in a semi-automatic taping machine. The roll of tape is fixed in front of the sleeve that is positioned on a shaft, and a compressive roller is used to attach the tape without creating air bubbles. When sleeves are taped and clichés created and correctly sorted, they are placed in the mounting machine where the clichés automatically are positioned onto the sleeves. Thus this machine is the one eliminating manual mounting.

After the clichés are mounted onto the sleeves the final step is to process them. In the Easy ITS process the entire sleeve is placed in the Processor that removes the remaining unhardened polymers. The Easy ITS processor combines three of the machines used in Pre-press today since it includes processing combined with drying and light finishing. When the sleeve exits the Easy ITS Processor it is, if not scheduled for a quality control, finished and ready to be sent to printing.

D Theoretical Framework

In this chapter the theoretical framework on which the study is based is described. As an introduction the theory of human and machines as a joint cognitive system will be described. This theory will be one of the foundations of this thesis. Secondly the term usability is described to clarify the goal for any product development process. Following, automation and its different types are discussed; with emphasis on the impact automated processes will have on people.

To get an overview of human error and how this can be investigated, human reliability assessments are also described. Finally general factors affecting the everyday tasks at a production site are further described. Cognitive and physical factors such as manual handling, shift work, development/improvement projects are briefly mentioned.

1. Human and machines as a joint system

Technical developments during the last centuries have succeeded in developing efficient and reliable machines that have become a large part of humans' everyday life. Despite this emphasis on machines the human operator is still an essential component, especially in critical situations (Hollnagel, 2005).

A common comprehension today is that technology and humans are independent components, only linked by input and output, where characteristics and possible errors that occur can be linked to one of the two. During the late 1960s the approach of seeing humans and machines as separated components was strong and focus was put on the interaction between the two. This model has been strong within the human factors engineering and human computer interaction fields and has worked as a good model for experiments and theories (Hollnagel, 2005).

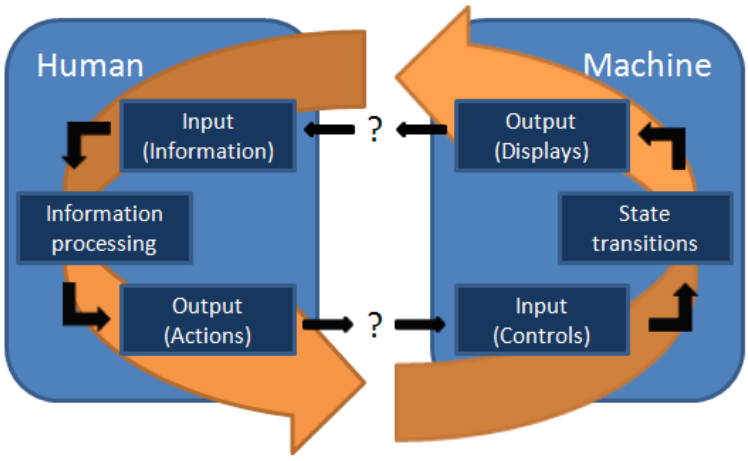


Figure D.3 The human-machine model, original model can be found in Hollnagel (2005)

However, a fundamental limitation with the human-machine model presented above (figure D.1) is that it separates the human and the machine instead of seeing them as a whole (Hollnagel, 2005). During the

last two decades these discussions have grown and more and more researchers have begun to emphasise the importance of focusing on the combination. Many researchers, for example Christoffersen and Woods (2002), argue that it is important to focus on the coordination of humans and machines and that human and non-human agents should not be separated. One example of this collaboration is artefacts, objects that mediate interaction between components of the world (Säljö, 2000; Sharp et al., 2007). They can be either physical, or in some cases abstract, tools that contain human expertise and explicit functions. Despite the fact that the machine contains human knowledge it is still important to be aware of the fact that they cannot function on their own and has to be interpreted to make sense. Artman and Garbis (1998) go as far as to consider artefacts to be *"cognitive catalysers",* since they contain *"the necessary but not the sufficient information"* (Artman and Garbis, 1998 p.5). Artefacts require human interaction and can be responsible both for enhancing and degrading human expertise (Christoffersen and Woods, 2002).

The researchers quoted above have in common that they believe that machines and humans have to coordinate as one team, one joint cognitive system and therefore it is important to design for fluent interactions. Christoffersen and Woods (2002) go one step further by expressing that when complex systems become automated, automation has to be considered to be a new team player. This will change the nature of interactions and thus needs to be considered in any implementation.

In this Master Thesis automation is seen as another component in the system that needs to be considered to enhance the collaboration between humans and machines.

2. Automation

With industrialization and the latest decades increased use of computers the use of automation has rapidly grown. Automation can be said to be *"the act of implementing the control of equipment with advanced technology; usually involving electronic hardware"* (The free dictionary, 2011). The classic aim with automation is to minimise the need for humans to perform either manual work or cognitive problem solving, and use machines or computers instead (Bainbridge, 1983). The goal is often to improve performance of routine tasks while reducing operator workload (Cacciabue 2004).

Today more and more processes become automated and one of the main reasons for this is cost savings. Depending on the reason for automating parts of a process, and on the intention, solutions take different form. One of the most common reasons is dangerous tasks where robots, in for example nuclear environments, are used to prevent physical injury. Other reasons are tasks that are challenging or even impossible for humans. A challenging task might be performing the same repeated simple mathematics task over and over again. Often a task that can be done by a computer in seconds can be almost impossible for the human brain to get right. In some cases humans are still performing the task but machines are supporting their actions. For example can the contact list in mobile phones function as an artefact that supports the human memory (Säljö, 2000)

Just as there are different reasons for automating a system there are also different levels of automation. Groover (2008) has divided automated production systems into categories based on system element

characteristics. First he divides automated elements of a production system into two categories: automation of the actual manufacturing in the factory, or computerization of the support systems. In modern production systems the categories tend to overlap as the manufacturing systems to some extent are controlled by and connected to a support system. The following text about automation is based solely on Groover (2008), except when parallels have been drawn to the level of automation of the equipment in the Easy ITS process.

2.1. Automated manufacturing systems

Automation solutions in manufacturing involves operations such as processing, assembly and material handling and are called automated since there is a decreased need, or in some cases no need at all, for human participation compared to when the same actions are done manually. These systems can in turn be divided into three subcategories: fixed automation, programmable automation and flexible automation, suitable for different production quantities and product variations.

Fixed automation

In fixed automation, the processing sequence is fixed and fully decided by the manufacturing equipment which usually involves a combination of multiple simple processing steps. The combination and coordination of these multiple operations is what makes the system complex. Characteristic for fixed automation are high initial costs due to customized equipment, high production rates and limited possibility for production variety.

In the Easy ITS line the processor is an example of fixed automation, where multiple steps have been combined into one. The processer contains functions that before was done in three different machines, and thus the handling between these steps are avoided too. The customization is high to suit the production need and there is only a small possibility to vary the production once implemented.

Programmable automation

In programmable automation, parameters entered to a program customize the operation sequence which accommodates varied product configurations. Compared to fixed automation there tend to be lower production rates, hence there is a larger flexibility and a high suitability to for batch production.

Flexible automation

By developing programmable automation, allowing the system to produce a larger variety of parts minimising time-loss due to changeover, it becomes even more flexible. In flexible automation there is no lost production time when altering machine setup and reprogramming the system and the system can produce various mixes of products not requiring fixed batch sizes. To make flexible automation possible there has to be only small differences between product varieties so that system changeover is minimal.

In the Easy ITS line the mounting machine is an example of flexible automation (or programmable). In this machine batch sizes and additional parameters need to be altered to suit different package sizes, i.e. size of clichés and sleeves. At the same time there is limited variability and the different choices available can be predefined.

2.2. Computerized support systems

The goal of computerized support systems is to minimise the need for clerical and manual effort in the different steps of the business process. Today computer systems are involved in almost all parts of the production cycle involving all steps from design of the product, plan and control production to organise additional information.

At Tetra Pak all production is planned and handled using the software program P2, a system that covers the production of packaging material and additional material. P2 interacts with outside systems and the production equipment to facilitate order planning and production. Additionally the state of the orders can be followed by changing the status when the material has gone through one of the processing steps (Interviews).

3. Accidents

An accident is an *"unforeseen and unplanned event, which leads to some sort of loss or injury"* (Hollnagel, 2004, p.4). In other words, accidents are short, sudden and unplanned events that results in an unwanted outcome. The event must somehow be the result of human activity and something happening fast rather than developing during a long time period (Hollnagel, 2004).

When viewing an accident as a combination of the event and the outcome, accident prevention can be directed at one of the two. As illustrated by figure D.2 below, even if an event cannot be prevented there is still a chance to prevent the outcome.

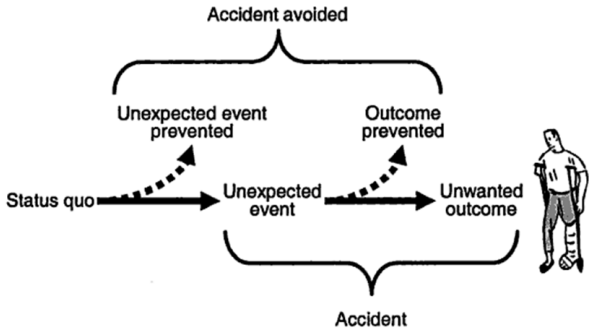


Figure D.2 Accident model, taken from Hollnagel (2004)

The outcome of an accident tells something about how serious the accident is and how unexpected it is can be seen as the likelihood of it happening and together they indicate the risk of the accident. In all systems there is always a chance of an undesirable event to happen which is captured in Murphy's Law that states that everything that can go wrong sooner or later will. According to Tenner (1997, p.22) the actual words Murphy said were: *"if there's more than one way to do a job and one of those ways will end in disaster then somebody will do it that way".* Accidents can occur on all levels in a system with consequences ranging from almost insignificant to major (Hollnagel 2004).

3.1. Accident models

It is very important to have a common frame of reference and understanding when discussing accidents. Accident models are methodical ways of thinking about how an accident occurs (Hollnagel, 2004) and are used to understand the causes of an accident and illustratively link technical, human and organizational contributions. A well structured accident model will also support the design of preventative measures.

The accident pyramid (figure D.3) exemplifies the importance of mutual understanding of what is considered to be an accident. It was originally developed by Heinrich in 1931 and has since then been updated to suit different contexts. This version is based on a study done by Bird (1969). The pyramid illustrates that for every fatal accident reported, 10 serious accidents, 30 accidents and 600 incidents with no visible injury or damage, are reported (Radvanska, 2010). Further there is an even larger uncertainty regarding near missed, all acts that could have lead to an injury or property damage. The number of cases in each category depends also on the definitions used when reporting and when getting further down in the pyramid issues are reported with less consistency and reliability (Hollnagel, 2004).

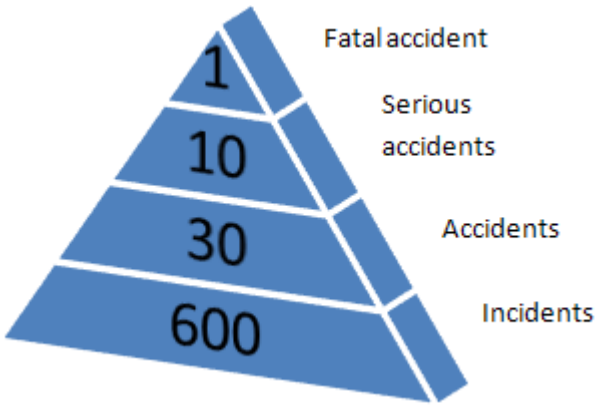


Figure 4 Accident pyramid

A number of accident models exist that in different ways try to explain why accidents occur. The models range from simple uncomplicated models towards more complex trying to describe the coordination of humans and machines. In this Master Thesis accidents are viewed through the accident model called the Swiss Cheese Model. It was chosen because it looks at combinations of actions and circumstances as the cause of an accident.

The Swiss Cheese Model

In the Swiss Cheese Model several factors are considered when investigating reasons for a potential accident. The model illustrates how unsafe acts and latent conditions can combine to get through barriers and hence cause the negative outcome. The Swiss Cheese Model has been updated since the first edition came in the 1980, figure D.4 below is the most recent version (1997) and the first one with the cheese analogy (Reason, 2008).

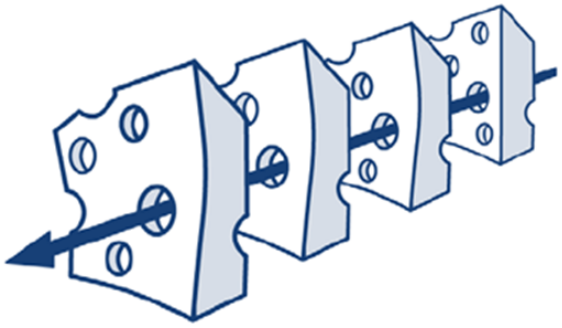


Figure 5 Reasons 2008 Swiss Cheese Model (The Royal Australian College of General Practitioners, 2010)

Each 'slice' has holes that can move around and it is only when a series of holes line up and coincide that an accident can pass through all barriers. The holes result from unsafe acts and latent conditions. These latent conditions arise because designers, managers, etc. cannot foresee all possible accident scenarios. Latent gaps have longer duration than gaps due to active failures and are present both before and after unsafe acts take place (Reason, 2008).

3.2. Accident prevention

As written above an accident can be avoided by either preventing the unexpected event or avoiding the unwanted outcome. Foremost the goal is to prevent the issue from happening in the first place, but when this is not possible the negative consequences should be mitigated. Hollnagel (1999) discusses the importance of barriers to understand and prevent accidents. The fact that an accident happens means that one or more barriers were missing or failed but if the pathway of the accident can be identified it can be prevented it the future (Hollnagel, 1999).

As seen in the Swiss cheese model unsafe and latent conditions can occur on different stages of a system and hence different barriers are suitable for different occasions. There are many different ways to prevent and to find the most suitable solution it is necessary to have a thorough understanding. To do this it is important to investigate the different components of the system and its context. It is not until then that potential incorrect actions and potential accident pathways can be charted and avoided.

4. Human Error

An error is something that involves some kind of deviation (Reason, 2008). Today a range of definitions exist explaining the term but there is still not one universal that can be applied to all circumstances. The errors can vary in severity but the definition in this analysis will be "something that will have a negative impact on the end result". It is important to differentiate between errors and violations. Violations are actions performed even though the human knows that the execution conflicts with how the action should be performed. Examples can be a routine of not performing a process step or that a recommended procedure is not followed (Embrey, n.d.).

Potential errors can be divided into latent and active failures, failures that in time can lead to erroneous actions or errors at the sharp end of the process, by the operator. Active failures are done actively by

the operator. By systematically going through each step of a work process, errors on each level can be detected. Latent errors are errors that are not performed by the operator at the sharp end, i.e. the person directly operating the systems. Latent errors can also be preconditions for unsafe acts (Reason, 1990), conditions that might influence the operator's performance negatively during the process. Examples are: tiredness, stress or environmental factors dividing the operator's attention. These issues are discussed in the second part of *Results – Current situation analysis* (F:3).

Another way to categorise errors is based on type of action. The categorisation can be either task-specific or general. Examples of categories are: *Omissions* (a step is not done when it is supposed to) and *Wrong objects* (the right action is done, but on the wrong object). Error classification based on action fails to explain underlying processes as it does not say anything about why an act is done, and hence will not be described in depth in this section. However a major advantage of using this approach is that there is a high consistency among classifiers, giving the approach a high inter-reliability. A similar taxonomy will be used when carrying out the human error identification (See the description about the SHERPA technique in (D:7.4) for a description of the taxonomy used).

A broad range of methods today exist to investigate and ultimately reduce human error. In chapter D:7 the ones relevant for the following study are described.

5. Automation and the human

Despite the fact that automation and technology have improved and facilitated many everyday tasks there are still factors to be questioned and there are many disbelievers (Sheridan, n.d., Bainbridge, 1983). While automation can be said to minimise human mistakes done at behavioural level, new safety critical issues related to errors of cognition are introduced and it is not enough to just automate to prevent failures.

According to Cacciabue (2004) these issues are correlated and affected by socio-technical contextual conditions such as training, previous experience, and both the physical and organisational working environment. He emphasises the importance of making use of both human skills and automation and their potential for preventing and recovering from human errors. Kirwan (1992) shares this view and means that as engineering has started to control some of the problems attributed to complex systems more and more risks are attributed to human error.

When machines perform more of the actions previously done by humans there is less need for human involvement and thus there are fewer possibilities for human error. However this is the case when everything goes as planned; in critical situations the need for humans to intervene and act is often extreme (Hollnagel, 2005).

Also Groover (2008) emphasises the continuous need for humans, especially for tasks where there is a high level of decision making, learning, managing and evaluating. Equipment maintenance for example is one area where the need for skilled personnel will continue. Humans are also needed to drive continuous improvement to solve technical problems and continue to develop existing solutions. As staff might decrease there is an increased need for people taking responsibility for plant operations and

Groover believes that this will lead to an increased need for technical skills compared to personnel in management positions. One example of Maintenance etc is Tetra Pak's Autonomous Maintenance (AM) pillar in their World Class Manufacturing (WCM) work. WCM teams are a good example of when continuous improvement projects are used to improve system performance, see chapter D:10 about WCM work at Tetra Pak.

Norman (1990) proposes that the problem is not the fact that a process becomes more automated; the problem is instead inappropriate design. He emphasizes that despite the fact that automation can perform the task satisfactory under normal operating conditions, it is not powerful enough to handle all possible abnormalities (Norman, 1990).

This leads to new challenges when designing with usability in mind and is another example of why it is important to consider the whole system.

6. Designing for the user

To be able to design for the interaction between humans and machines it is important to consider the user already while developing the end-product. User-centred design is a way to ensure that the users are present on all design stages.

6.1. User-centred Design

User-centred design is based on the premise that the best systems and products are designed with the user in mind and by understanding their needs. To do this, designers actively engage with the users to gather their insights, instead of relying on their own beliefs about the users. This is done throughout the process from gathering user requirements in the beginning of a project to getting feedback on prototypes and the finished solution. It is especially useful to work with a user-centred approach when introducing a completely new product because this gives designers a chance to question established practices and assumptions (Black, 2008). Additionally, it is important to start engaging the users on such an early stage that their opinions still can matter and that design changes still are possible.

A common initial approach is user observations where the designer immerses in the user environment to understand in what context the end-product will be used and to gather additional requirements. Asking open ended questions while observing often gives the user-centred designer a deeper understanding and therefore unexpressed needs and interactions can be identified (Black, 2008).

In later steps it is useful to do user evaluations of developed prototypes. The complexity of these prototypes varies depending on development phase and can range from paper sketches to interactive prototypes. Depending on the prototype complexity different methods are useful for data gathering. When gathering user input it is beneficial to observe and talk to the widest possible range of users, likely to interact with the end product (Black, 2008).

In the *Human Factors Methods* section within the *Theoretical Framework* (D:7), the methods relevant for the study in this Master Thesis are described. The choice of methods is motivated in the *Methodology* chapter.

6.2. Usability

Usability means ensuring that interactive products or systems are easy to learn, effective and efficient to use, safe, and enjoyable for the considered user. To make sure that a product is usable usability has been broken down into six specific goals:

- Effective to use – How good is the product at doing what it is supposed to do?
- Efficient to use – Is the product supporting the users when performing the task?
- Safe to use – Does the product protect the users from potentially dangerous situations?
- Having good utility – Does the product provide the right functionality to perform the task?
- Easy to learn – How easy is it to learn how to use the product?
- Easy to remember – Once learned, how easy is it to remember how to use the product?

To ensure that a product fulfils the criteria, more detailed questions about each goal above in relation to the product, have to be considered. For example can the question: *"What is the range of errors that are possible using the product and what measures are there to permit users to recover easily from them?"* helps to ensure that a product is safe to use. When considering usability it is important to understand the product in its context. Therefore it is necessary to consider and define the target user group, the context of use and finally the characteristics of the task performed. To do this a thorough analysis of the human machine interaction is beneficial (Sharp et al., 2007).

One of the main purposes of this Master Thesis is suggesting usable solutions for the new machine line developed in the Easy ITS project. To do this the context of use is investigated by performing observations and interviews. The data is presented and analysed using Task Analyses and Human Error Investigations presented in chapters F and G. Hence, the solutions in the last chapters of this Master Thesis will be developed with usability in mind.

6.3. Mental models

It is important that the user of the system and the designer have the same understanding of the functionality and usage. Through the interaction with the system the user will hopefully receive the understanding intended by the designer. Norman (1986) discusses the conceptual model (illustrated in figure D.5) of a system where it is important to acknowledge that the designer cannot communicate directly to the user, instead all communications takes place through the system image (Norman, 1990). Therefore when the system image is not fully representing the idea of the designer or lack consistency the user will end up with the wrong mental model.

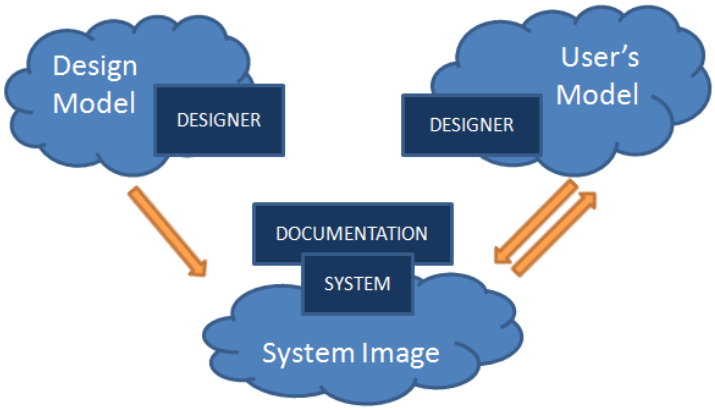


Figure 6 Illustration of Norman's Conceptual model (1986)

Norman defines the system image to be the visible part of the system which implies the importance of the design of displays and alarms.

6.4. Auditory alarms

Alarms can be either visual or auditory, but since the auditory system is omnidirectional (the signals can be sensed no matter how we are oriented) these alarms are recommended when the alarm signal *must be sensed* (Wickens, 2004).

When designing alarms it is important to do an environmental and task analysis to understand other noises in the environment. By doing this, detectability can be guaranteed while minimising disruption of other important tasks. Additionally it is important to consider what the alarm should communicate and how important the signal is to quickly perceive. By fully understanding the task being performed and its context the alarms can be planned in relation to each other. Additionally they should be designed not be confusable with other alarms and absolute judgement should be avoided (Wickens, 2004).

7. Human Factors Methods

As mentioned in the introduction and in the first chapters of this section it is important to understand the whole picture. When designing products it is important to define context of use and preferences of the users. This information can be elicited using different Human Factors methods. In this chapter the methods relevant for the following study are described.

Initially, observations and interviews, two methods for eliciting information are described. Afterwards Task analysis, a way to organise information, and human error identification is described.

7.1. Observations

Observations are useful methods to gather real-life information about a topic. If conducted correctly they can give valuable objective data and are often used as a complement to other data collection methods. Observations are especially useful when an ongoing situation or event takes place and there

are observable physical objects that are readably seen (Taylor-Powell and Steele, 1996). Interactions can then be studied; both between humans and between objects and humans.

Observations can be either structured or unstructured and Taylor-Powell and Steele equalises this with either looking for something or looking at something. Structured observations can provide quantitative data about for example frequency counts, rankings and ratings. They are used when there is a need to standardise information and usually guided by a preset checklist of what to observe. On the other end unstructured observations are more interested in seeing things within the participants' context and are strongly linked to anthropometry. The produced data is qualitative and can provide data the observer did not expect to find.

Prior to conducting an observation the following working steps can be followed to facilitate the observation, see table D.1.

Table D.1 Observation process guidelines

Observation process guidelines	
1. Define study requirements	Before the study it is important to consider the requirements necessary to complete a successful observation. One example of a study requirement is access to the object of observation.
2. Define scenario observed	Prior to the observation the characteristics of the scenario need to specified to make sure the observation is designed appropriately.
3. Design observation	It is important to clarify what is to be observed before the observations not to miss information relevant and important for the study.
4. Conduct pilot session	To see that the information of interest can be captured in an observation it is recommended to start the study with at least one pilot session. The scenario chosen or the design of the observation can then be altered if necessary.
5. Conduct observation	The observations should be conducted according to the specified plan. This to make sure the data received is correct and of the desired type and also to validate a future analysis of the data collected.
6. Data analysis	Depending on study purpose different data analysis methods can be chosen. In this study task analysis and the human error identification method SHERPA are used. Descriptions about these methods can be found in section 7.3 and 7.4.

7.2. Interviews

An interview can be defined as a *"guided conversation between a respondent and an investigator"* (McClelland and Fulton-Suri, 2005) and is a frequently used method when in depth information is gathered. Interviews are specifically useful for encouraging users to explore issues and obtain detailed information about a topic (Sharp et al., 2007; Wilkinson and Birmingham, 2003). Furthermore interviews are useful for capturing opinions and subjective judgements to understand complicated cause and effect relations (McClelland and Fulton-Suri, 2005). As interviews are very resource intensive the selection of interviewees is critical (Wilkinson and Birmingham, 2003).

Interviews can be structured, semi-structured or unstructured depending on how much control the researcher wants to have over the discussion. The structured interview can be equalised with a verbal questionnaire, completed face-to-face. This is because the questions are predefined, just as with handed out written questionnaires. Beneficial with this approach is that the interviewer does not need an in-depth knowledge about the subject, and the data becomes easier to analyse. At the same time it is difficult to know beforehand where a discussion might end up and what the participants have to say. An unstructured interview is similar to a spontaneous conversation with no predefined questions. This type of interview often requires more background information for the researcher in order to get the conversation going and also to identify what issues should be further developed. It is however beneficial in the way that unexpected information is more likely to come up (Wilkinson and Birmingham, 2003).

McClelland and Fulton-Suri (2005) recommend using props during an interview to work as a catalyst provoking responses. By representing the design in some way, for example with a picture, the communication is facilitated. Equally important, if not more, is that the interviewee is at ease during the interview and the goal is to create a sense of *"conversation rather than inquisition".*

When conducting the interviews it is important that the interviewees have the sought knowledge and can verbalise it and that they can understand the questions. It is also critical that the interviewee is not influenced by things such as participants, questions, props or surroundings when answering questions.

After an interview the collected data needs to be transcribed and this is a time-consuming and sometimes troublesome task. Troublesome due to the fact that information is easily misinterpreted and it is often a large amount of information to handle and structure simultaneously. Transcribed material can and should be presented to the interviewee to make sure they agree with the processed results.

Prior to conducting an interview the following working steps can be followed to facilitate the interview, see table D.2.

Table D.2 Interview process guidelines

Interview process guidelines	
1. Sampling	First the interviewee sample is chosen. It is important that the interviewees represent the population being studied without requiring a too large sample since the method is resource intensive.

2. Obtaining an interview	Obtaining an interview can be the limiting factor. It is therefore important to set the time for the interview as early as possible.
3. Designing the schedule	For both structured and unstructured interviews it is important to consider the questions prior to the interview.
4. Asking the questions	During the interview it is important not to affect the interviewees with how the questions are asked. Additionally it is recommended to create a relaxed atmosphere so that the interviewee feels at ease.
5. Recording the response	Not to miss information it is recommended to record the responses. A common way to do this is using a dictaphone or a video recorder, alternatively taking notes.
6. Analysis	After the interview the data is transcribed and a data analysis method suitable for the study is chosen. It is important to consider the type of data analysis already when planning the interview so that the right type of data is collected.

7.3. Task Analysis

A Task analysis is a problem solving method that functions as a way for the analyst to elicit and organise information. When studying work tasks it is important to map and systematically structure the steps of the work task in order to visualise and understand the process. This visualisation can then be used as a base for analyses and in discussions allowing structured feedback on interpretation of data, making sure those who are conducting the study are heading in the right direction. Using a structured method also helps to guide the analyst's decision process to systematically explore how improvements can be done (Shepherd and Stammers, 2005). A systematic representation of a working process may also serve as a basis for human error identification as is used in this Master Thesis study.

The analysis begins with the overall goal of the task and progressively becomes more detailed by creating sub-goals in the form of operations needed to be executed to achieve each goal. For each sub-goal a more detailed description with additional sub-goals is considered until the level of analysis is sufficiently detailed. Furthermore plans can be integrated as a way to illustrate the sequence in which the operations are executed (Stanton, 2004; Shepherd and Stammers, 2005).

In larger studies it is very important to organise collected information in a systematic manner so that nothing is lost and to facilitate presentation at a later stage. The collected information should be presented in such a way that feedback may be given by key actors who can approve and validate the interpreted information. To use straightforward text as a means of presenting the information about the work process is in some cases recommended and formal language should be avoided. In doing this, little room is left for interpretations as is common when studying for example tables or diagrams. Of course if

the study is very large, tables and diagrams give a better overview of the work process, which is the case in this study (Shepherd and Stammers, 2005).

Hierarchical Task Analysis (HTA)

In this project hierarchical task analysis (HTA) will be used as a method of creating a task analysis. A HTA is a way of presenting a task analysis by structuring the goals and sub goals hierarchically in a visual tree. At the top is the main goal, for example creating a cliché. Below, this goal is divided into sub-goals together making up the top goal. The depth of the hierarchy represents the depth to which the task analysis is done.

Initially it is important to get a general view and explore the context of the work task and its connection to other activities in the organisation. Establishing what aspects of the organisation are relevant makes it easier to locate useful information. It is recommended to also identify key actors in this early stage whose perspective and knowledge may be obtained during the process. These key actors are also important for establishing a proper relationship to the client. In observing the context it is possible to obtain an indication of what the task is, what resources are available to undertake issues arising and also map various constraints in the tasks involved (Baber and Stanton, 2002).

There are several relevant methods to gather information, among them; interviews, verbal protocol analysis, questionnaires, observations, simulations, and examining production and safety records.

7.4. Human Reliability Assessment

To investigate what can go wrong in complex large-scale systems, probabilistic risk assessments (PRA) can be performed. These assessments are predictive ways to systematically get a comprehensive evaluation of the potential risks to a system. Based on definitions of what is considered to be an undesirable event a PRA can be used to identify what failures and events that can, either alone or in concert, lead to negative consequences (Kirwan, 1992).

With the increase in focus towards human errors it has become important also to consider the impact of possible human errors in risk assessments. One way to assess the human error contribution to risks is by using human reliability assessment (HRA) tools. Kirwan describes three steps that are considered to be the core of HRAs (Kirwan, 2005).

1. Human error identification
2. Human error quantification
3. Human error reduction

During the 1970s and 1980s, the first major decades of HRA, the focus was on the development of quantification techniques. Human error quantification (HEQ) methods calculate the probability for the occurrence of a human error (HEP) which is defined in equation D.1 below.

Equation D.1 HEP calculation

$$HEP = \frac{Number_of_errors_occured}{Number_of_opportunites_for_error_to_occur}$$

The ideal data source would be real data collected from the industry about both performance and number and type of accidents. However, it is common that data is not collected. Reasons for this might be a lack of awareness of why it is useful to collect this type of data and reluctance to publish data on poor performance. Different human error quantification techniques are dependent on different types of data, ranging from lab experiments and simulations to expert judgements. For each method there are trade-offs between practicality and ease of use, and the validity and similarity to the real world (Kirwan, 2005).

These initial methods, i.e. human error quantification methods, have been criticised for not being sufficient for safety analyses of modern human-machine systems (Cacciabue, 2004; Kirwan, 2005) Cacciabue argues that they focus too much on quantification, and hence neglect to consider causes and reasons, the cognitive processes that underlay human performance and behaviour. Kirwan (1992) stresses that human error identification (HEI) methods are necessary to be able to obtain solutions to recover from, and mitigate the consequences of, human error. Human error identification techniques have been used for many years now and many different methods are used within a broad range of industries (Lane et al., 2006; Salmon et al., 2003). HEI techniques can be used either during the design development phase or to evaluate the potential for error in existing systems (Salmon et al., 2003).

In this Master Thesis the focus will be on human error identification (1) and human error reduction (3). Quantifications will be done as a mean to compare the existing machine line and the Easy ITS line under development.

Identifying human errors is the most critical part of HRA, since adding irrelevant errors or omitting significant will affect the analysis. This will in turn lead to that the effects of human error to a system will be either underestimated or overstated. To ensure a high level of reliability and including all possible errors while maintaining objective it is of high value to use a systematic methodology.

The typical output of a HEI technique is usually potential errors, their consequences, recovery potential, probability, criticality, and includes a strategy to reduce the errors. A range of different HEI techniques exist today with different application areas and taxonomies used, i.e. how the errors are categorised. One of the most common ones is taxonomic based HEI techniques where error modes are applied to each task step of a process. These techniques tend to be quick and easy to use and are typically the most successful in terms of sensibility. On the other hand reliability has been questioned due to subjectivity, and the analyses are likely to give different results both between analysts (intra-analyst) and occasions (inter-analyst).

One of the most common Human error identification methods, that also has received respect since it is broadly used and tested, is the *Systematic Human Error Reduction and Prediction Approach (SHERPA)* (Salmon et al., 2003*).*

7.5. Systematic Human Error Reduction and Prediction Approach

The SHERPA technique was developed in 1986 by Embrey as a method originally used to support people in process industries (Stanton, 2004). It is especially useful in high-risk environments where tasks are complex and there is a large risk for error. By using a SHERPA the goal is to identify where in the process errors occur to be able to apply solutions to prevent these (Lane et al., 2006). Initially oil and gas were typical application areas and multiple studies have been executed to evaluate both the system itself and the use of the method. During the latest decades the areas of use have broadened and for example the uses of ticket and vending machines (Stanton, 2004) or medical administration (Lane et al, 2006) have been evaluated using the approach.

As mentioned in the *Theoretical Framework* (D:2) a more automated system can lead to previously unexpected human errors. The contexts in which the SHERPA technique tends to be used all have in common that they have clearly defined processes which is also the case for the processes studied in this Master Thesis. More reasons for choosing the SHERPA technique can be found in *Methodology* (E).

SHERPA uses hierarchical task analysis combined with error taxonomy to identify potential issues. For each task step possible errors related to actions, retrieval, check, selection or information communication, are considered (Salmon et al., 2003).

Advantages and disadvantages with the technique

The SHERPA is widely used and both advantages and disadvantages have been discussed on multiple occasions. The main ones, listed in table D.3 below, are taken from Stanton (2004):

Table D.3 Advantages and Disadvantages with the SHERPA approach

Advantages (+)	Disadvantages (-)
•Structured and comprehensive procedure •Taxonomy supports analyst to find all potential errors •Validity and reliability of data high due to structured procedure •Saves time compared to observations •Error reduction strategies areintegrated in the procedure	•Time-consuming for complex tasks •Additional work if HTA is not already available •No consideration to cognitive components of error mechanisms •Risk of predicting unlikely errors •Taxonomy can lack generalisability •Latent errors are not included in the framework

Performed correctly the SHERPA is a comprehensive approach that facilitates finding all potential errors. It takes time to perform the technique for complex tasks and reasons for the errors are not considered. Since potential errors are sought at every step of a process there is a risk of predicting unlikely errors.

One large advantage of using this technique is that error reduction strategies are considered in the procedure.

Procedure

Stanton (2004) offers a useful overview of the approach and describes the eight steps of the procedure. To fully understand the value and objectivity of the method, each SHERPA step is here described.

Step 1: Hierarchical Task Analysis (HTA)

The first step of the process is to analyse the work activities and structuring these by constructing a hierarchical task analysis (HTA). For more information about HTA see section *5.3 Task Analysis* above.

Step 2: Task Classification

When the information has been structured into the HTA each operation on the bottom level becomes the subject of interest. Firstly each operation is classified according to the following error taxonomy (table D.4):

Table D.4 Error Taxonomy, (from Stanton, 2004, p37-2)

Error type	Examples
Action	Doing something: pressing a button, pulling a switch, opening a door
Retrieval	Getting information from a screen or manual
Checking	Conducting a procedural check
Selection	Choosing one alternative over another
Information communicated	Talking to another party or writing down information

Step 3: Human-Error Identification (HEI)

For each operation, possible errors are identified and described and the form categorised according to the following error taxonomy (table D.5):

Table D.5 Taxonomy of Credible Errors (from Stanton, 2004, p37-3)

Action Errors		Checking Errors		Retrieval Errors		Communication Errors		Selection Errors	
A1	Operation too long/short	**C1**	Check omitted	**R1**	Information not obtained	**I1**	Information not communicated	**S1**	Selection omitted
A2	Operation mistimed	**C2**	Check incomplete	**R2**	Wrong information obtained	**I2**	Wrong information communicated	**S2**	Wrong selection made
A3	Operation in wrong direction	**C3**	Right check on wrong object	**R3**	Information retrieval incomplete	**I3**	Information communication incomplete		
A4	Operation too little/much	**C4**	Wrong check on right object						
A5	Misalign	**C5**	Check mistimed						
A6	Right	**C6**	Wrong check						

	operation on wrong object	on wrong object
A7	Wrong operation on right object	
A8	Operation omitted	
A9	Operation incomplete	
A10	Wrong operation on wrong object	

An action can for example be either omitted, incomplete or in some way performed incorrectly. For each task step more than one error can be credible (Stanton, 2004).

Step 4: Consequence Analysis

The next step is to consider the consequence of each error. The consequence will influence the criticality of the error defined in step 7. For example if the wrong button on an alarm clock is pressed the consequence might be oversleeping.

Step 5: Recovery Analysis

If the error can be detected and recovered in a later task step this is noted. To be able to do this the goal has to be clear. Assumptions and confines that will influence the results of the following study can be found in the *Methodology* chapter.

Step 6: Ordinal Probability Analysis

In the next step the probability that the error occurs is defined, based on expertise and/or historical data. The probability is rated in three levels: low, medium, or high. Low (L) is for errors that has never been known to occur, Medium (M) for errors that have occurred in the past, and finally High (H) for errors that occur frequently.

Step 7: Criticality Analysis

The criticality can be rated in different ways, where some analyses use a three level rating with Low (L), Medium (M) and High (H) similar to the probability rating (Lane et al., 2006). This study uses the binary rating, described by Stanton. Errors that lead to a serious incident are labelled as critical (!). Critical consequences could for example lead to considerable damage to material, factory site or operators.

Step 8: Remedy Analysis

In the last step of the procedure ways to minimise the described errors are suggested. The primary goal is to suggest changes that can prevent the error from occurring but in cases where this is not possible the goal is instead to mitigate the negative consequences (see similar discussion in chapter D:3.2 Accident prevention). The strategies to reduce the effects of an error or the actual error are developed through “structured brainstorming”.

The remedial strategies vary in difficulty to implement. Some are costly and others need time to create and maintain a difference. Often all recommendations can and will not be followed and it is therefore necessary to clearly indicate which strategies should be prioritised.

SHERPA Example

In table D.6 the information structured in the SHERPA from the task of programming a video cassette recorder is provided as an example of the steps just described.

Table D.6 Examples of the information about one task step after executed SHERPA

	Activity	Programming the VCR (Video Cassette Recorder)
1.	Hierarchical task analysis	Task 4.3 Set start time
2.	Task Classification	Error type: Information communication
3.	Human-Error Identification	Error description: Wrong time entered Error mode: Wrong information communicated (I2)
4.	Consequence analysis	Wrong program recorded
5.	Recovery analysis	None
6.	Ordinal probability analysis	L
7.	Criticality analysis	!
8.	Remedy analysis	Dial time in via analogue clock

Issues with human error prediction techniques

Stanton (2004) briefly discusses typical issues of existing human-error prediction techniques and primarily highlights two issues. Firstly the methods do not take enough consideration to the context in which performance occurs. Secondly the methods are highly dependent upon the judgement of the analyst. Consequently the reliability of the methods is low and often different analysts identify different issues or the same analyst may make different judgements on different occasions. To improve the chances of a realistic analysis it is helpful if the analyst is an expert in both the technique (e.g. SHERPA) and the operation of the equipment being analysed (e.g. the Pre-press process).

The SHERPA technique has been evaluated on multiple occasions and been given a high validity and reliability compared to many other human-error prediction techniques. However the quality is highly dependent upon the expertise of the analyst and the complexity of what is being analysed (Stanton, 2004).

Advantages and disadvantages related to the SHERPA method have been described above but in general when using a technique to predict human error it is important to question the actual probability of an identified issue to avoid being overly precautious. Additionally clearly defining the process steps before any analysis facilitates identifying the whole range of possible issues while remaining objective.

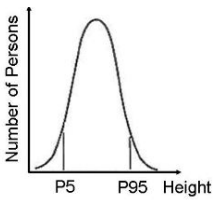
8. Physical Ergonomics

In this chapter the basics of physical ergonomics will be outlined and references to literature with information needed to plan and design an optimised workspace will be provided. The subjects

presented will be issues that can be related to tasks studied in the project. Some terms used and needed to outline those issues are also briefly explained.

8.1 Anthropometrics

When discussing physical ergonomics, anthropometry is a commonly used term. Anthropometry means the *measurements of the size and proportions of the human body* (Dictionary.com, 2011).



When discussing user data and what constraints to use percentiles are often used. As an example *P5 and P95* means including all users above the lowest 5 percent and beneath the highest 95 percent of a normal distribution of the complete population. This is illustrated in figure D.5.

Figure 7 Illustration for percentiles taken from TP Handbook

Considering that Tetra Pak is very much a global company and its products are used all over the world, data studied and recommendations given should not just focus on European data and user requirements but include all nationalities. Tetra Pak have chosen to include a large scope in their material for equipment safety with anthropometric values for a combined population ranging from the P5 of Japanese women and P95 for a Dutch male (Etzler, 2009).

8.2 RSI - repetitive strain injuries

The website RSI Awareness describes the term Repetitive Strain Injuries (RSI) as follows:

Repetitive Strain Injury (RSI) is the name given to a group of injuries affecting the muscles, tendons and nerves primarily of the neck and upper limbs. It is an umbrella term and is also known as Work Related Upper Limb Disorder (WRULD) (RSI Awareness website, 2007).

RSI or WRULD symptoms and diagnoses can be divided in two main types. Symptoms applicable for the first type of RSI are among others aches, pain, swelling, numbness, tingling, weakness and cramps (RSI Awareness). The second type of RSIs has no specific symptoms nor are the symptoms visible or named which make each diagnosis very complicated (Pheasant and Haslegrave, 2006).

It is very important to take action already at the early signs of RSI. It is both preventable and treatable, particularly if addressed early on (RSI Awareness website, 2007). Pheasant and Haslegrave (2006) summarise the results from epidemiological studies performed by Hagberg et al. (1995), Bernard (1997) and the National Research Council (1999) and conclude the work factors which have most consistently shown to be associated with WRULDS as; monotonous and repetitive tasks, hand work, high force, static muscle load and vibrating tools. *RSI Awareness* agrees and explains causes of RSI's as a combination of overuse and repetition, awkward or static posture and insufficient recovery time. Stress is also stated as a common factor. Pheasant and Haslegrave also suggest high perceived workload, low degree of influence and social support as psychological and organisational factors that may result in RSI (or WRULD) through psychological responses such as increased tension in muscles, increased symptom perception or changed work behaviour by for example skipping breaks.

8.3 Workspace design

When designing a workspace there are several aspects to consider. Pheasant and Haslegrave (2006) discuss a number of main factors in their book *Body space*. The main areas that are also relevant for this Master Thesis in the designing of workspaces are:

- Clearance
- Reach
- Posture

8.3.1 Clearance

Clearance considers the possibility to move around in the workspace. Relevant for all the above mentioned areas, the first step is to define who the user is and the anthropometry of the specific user. When discussing clearance Pheasant and Haslegrave (2006) suggest defining the *limiting user*, which is an imaginative user whose personal characteristics, both mental and physical, impose the strongest constraints on the workspace design. These constraints, also called requirements, can then be considered in deciding if a workspace is well designed.

They also mention three different ways of providing solution to different user requirements. Either the design is made to fit the limiting user or if there are two way constraints, for example lowest and highest work area, an area of common fit should be provided. Lastly a solution that provides adjustment possibilities is recommended.

The *Tetra Pak Equipment Ergonomics Handbook* recommends that improved or new design solutions should be tested by the operator before being implemented to secure the use of the tool/product and possibly find shortcomings with the design (Etzler, 2009). Pheasant and Haslegrave presents *fitting trials* as a way to do this, where the user is presented with an adjustable workstation where tasks can be simulated and the user may perform the tasks at for example different heights. The user can then give input on the different heights and an appropriate height may be set.

8.3.2 Reach

Reach constraints are used to determine the dimensional limits of an object. The ability to reach a handle or to work on an interface is one type of reach constraint, whereas visual reach constraints, such as being able to view an information board, is another type.

Depending on the force required for standing work the height differs, activities that require more force are for example facilitated by a somewhat lower height. The illustration below (figure D.6) is taken from the handbook.

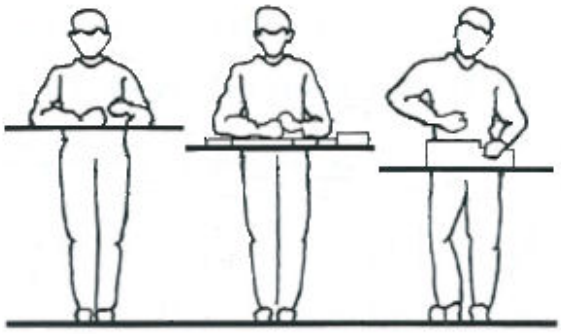


Figure 86 Different working heights for different types of standing work

For standing work a main recommendation is to work no lower than knee height and no higher than shoulder height but different types of work have different more specific recommendations. For example Pheasant and Haslegrave suggest lifting and handling tasks to be performed between mid thigh and mid chest and more manipulative tasks requiring moderate force 50-100 mm below elbow height. Furthermore delicate tasks are best performed at a height of 50-100 mm above elbow height. Reach dimensions are presented in detail in *Tetra Pak Equipment Ergonomics Handbook*.

Furthermore, depending on how often and for how long a task is done in combination with the precision involved the working area should be adjusted. In the picture below, figure D.7, an outer and an inner working area is shown, valid for 90 % of the Tetra Pak user population. It is always preferable to work within the inner working area, especially if a task requires precision or is done often. When precision is required it is important that arms and shoulders are relaxed. For tasks done less frequently the outer working area provides the recommended limit.

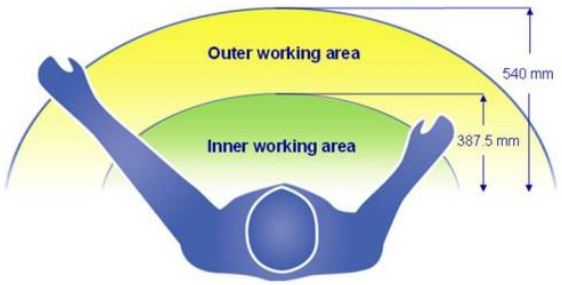


Figure 97 Recommended working areas

8.3.3 Postures

Frequent change of posture is always a good solution. If this is not possible it is even more important that an appropriate working posture is upheld. An appropriate working posture should be considered for standing as well as sitting and other types of postures.

Insufficient visibility on for example computer screens or other informative items often result in a forward inclination of head and trunk. To provide for example sufficient lighting or improve visibility in

other ways this can be avoided. For fine manipulative tasks with high visual demands, ISO standards recommend a tilt of no more than 15' (Pheasant and Haslegrave, 2006).

It is crucial to adopt a good posture when performing tasks requiring much force such as lifting, pulling and pushing which is further discussed in the following section.

8.4 Manual handling

Other than providing a well designed workspace the handling of the material used in a process is also of high importance because it often includes handling the same object several times each day.

Pheasant and Haslegrave (2006) discuss prevention of injuries stemming from manual handling in terms of two main questions;

- *What is the safest way of lifting heavy weights?*
- *What is the maximum safe weight a person can lift?*

To lift heavy weights in a safe manner the first and foremost rule is to always aim for the object lifted to be placed as close to the body as possible. This is to reduce the need to counterbalance the load and leverage forces on back and neck. Secondly, symmetric lifting actions are in general safer than asymmetric. Turning while lifting, also called twisting, is an example of asymmetric lifting. Both these issues can be affected and avoided by appropriate foot placement. It is therefore important that there is room for proper foot placement at all times. For example the action of picking up a heavy box from the middle of a large table makes it impossible to place the feet close to the box. Another fact presented is that the force of a human lift/grip is greatest at knuckle height. A safe weight is of course related to many other factors such as the strength and size of the person attempting to lift it, the shape of the object lifted or frequency of the lift (Pheasant and Haslegrave, 2006).

Carrying masses should also be considered in short, medium and long term. For example a medium weight may be alright to lift a couple times a day but when the action is repeated 20 times per shift it may not be as harmless any more. In the Tetra Pak handbook a table of acceptable weights and repetitions are presented (Etzler, 2009).

Manual handling of objects that are not lifted but still require force, such as pushing or pulling trolleys or

Pushing and pulling actions not only depend on the strength of for example the forearm but can also be affected by the body weight creating leverage or the positioning and design of the handle or contact surface. An appropriate contact surface helps to transmit the force and a good grip providing maximum force can facilitate the action (Pheasant and Haslegrave, 2006).

One of a human's most important tools is our hands. It is a phenomenal invention but has its limits still. The strength of our grip is very much dependent on the type of grip we use. One grip is called the power grip and is the grip giving us the most force. The pinching grip is the weakest of all grips, including only 25 % of a power grip. This means that four times as much force is needed to hold on to a flat object

compared to for example a handle for which the power grip may be used. Examples of the grips are found in figure D.8 (Etzler, 2009).

Figure D.8 To the left a power grip. Middle and right are examples of a pinching grip. (Taken from TP Handbook)

Connected to the use of our hands is of course the use of the wrist. *Carpel tunnel syndrome* is a type of RSI arisen from irritation of the nerve as well as entrapment and is caused by an extension of the wrist or repeated impact to the wrist, for example the use of a hammer or some type of vibrating tool (Pheasant and Haslegrave, 2006).

9. Organisational Ergonomics

9.1 Shift work

Shift work is becoming increasingly common in society today as a mean to produce more, and to be prepared around the clock. The reasons for shift work are many, and Monographs (1998) mentions technological needs (e.g. power plants and oil refinery), services/utilities functions (e.g. hospitals, transports and emergency services), productivity demands (e.g. paper, food and other processing industries) and the leisure industry to be the main ones.

Shift work has a high impact on companies' economic operations and is especially important when increased working hours is necessary to extend operating hours. High fixed costs, for example the use of expensive machinery in manufacturing, and pressure to meet time demands are two of the main reasons for increased operational hours (European Foundation, 2007).

Various definitions exist, however the general significance is usually the same, namely that shift work is *"a system of employment where an individual's normal hours of work are, in part, outside the period of normal day working and may follow a different pattern in consecutive periods of weeks"(*The Free Dictionary, 2011).

In the same manner as the definitions vary, so does the tendency to work irregular hours. As can be read from the Fourth European Working Conditions Survey, conducted 2007, there is a higher proportion of shift work in Eastern Europe. Here approximately 23 % of workers work some kind of shift work compared to 14 % in the Scandinavian countries (including the Netherlands). An even larger difference can be found between working sectors where approximately one in three employees in healthcare, works shifts, as opposed to only one in 20 in agriculture or one in ten in construction. Manufacturing is

another sector with a high proportion of shift work; here one worker in four works shifts. These numbers are in conjunction with the British public service trade union Unison's (2002) Labour Force Survey where they conclude that manual workers are more likely to work shifts than non-manual.

Shift work is known to have a negative impact on the workforce's health and has been the topic for many studies and articles on work environment (Åkerstedt, 1990). Also work unions emphasise possible issues and accent that it is crucial to pay attention to possible safety and health issues (Unison, 2002). Åkerstedt (1990) says that the major effects of shift work concern sleep alertness and performance but also long-term health implications. A range of different health issues (both physical and psychophysiological) can be related to shift work and many of these tend to be related to disruption of the body's circadian rhythms, quantity of sleep and social aspects (Union, 2002; Åkerstedt, 1990).

Circadian rhythms are physical, mental and behavioural changes in the human body that follow a cycle of approximately 24 hours. While produced by natural factors within the body and rather stable, the circadian rhythm is affected by environmental factors such as light, darkness, sleep, and food. The adjustment period to a new time pattern varies but tends to be around one hour per day (Åkerstedt, 1990). This time period is important to consider when planning shift schemes. When adapting to working night shifts this period might be even longer since night workers have harder to adopt their sleep pattern to fully take advantage of light hours when adjusting. To facilitate adjusting to new working hours it is recommended that the scheme changes clockwise.

9.2 Labour productivity

The concept of productivity and how it is best approached in communicating productivity demands to the employees is interesting in regards to this Master Thesis. Analyzing productivity is an important tool in increasing effectiveness and generalized profit. In his article *Productivity – Target or Conceptual tool?* (1965), Easterfield explains how productivity analyses both serve to identify limiting factors but also force people to define what it is they wish to achieve. It should be noted also that achievements are not always measured in figures of income or amounts produced but can also be represented by social or environmental responsibilities.

When performing productivity analyses, Easterfield highlights the risk of inappropriate measurement techniques which are often followed by misdirected actions to boost productivity. He also points out the importance of looking for concealed inefficiency. The productivity analysis needs to be made so that it is not possible to work around the measurements to create good results by being in fact less effective. As early as in 1965 he found that by regularly performing and publishing results from productivity measurements workers were stimulated to achieve good results and it gave them a stronger sense of involvement in the achievements of the company as a whole.

In many cases today the manual labour is in fact a strong limiting factor in increasing productivity in terms of effectiveness which is why many companies try to minimise this source in order to boost efficiency and production goals. However, an alternative way is to aim at increasing the efficiency and productivity among the employees.

Improving performance of workers involve both training and education and in many ways carefully improving and planning the communication between supervisors/management and employees. It is an ongoing discussion whether it is favourable to let employees set their own productivity goals as opposed to giving them a high target goal set by supervisors. In order to discuss this some key terms need to be introduced.

- Expectancy
- State expectancy
- Trait expectancy
- Subjective Probability of Success (SPS)

Expectancy was first described as an expression connected to the personal self, a subjective view of what may be achieved thanks to an individual. **State expectancy** is a broader term that means looking at expectancy in relation to circumstances and the situation. To perform a certain task the operators connect their expectancy of their own performance with regards to the circumstances they are given, not only depending on their abilities. Circumstances such as education and practice are in a way connected to the self but in state expectancy this is regarded as circumstances affecting the situation. **Trait expectancy** is an expression very similar to expectancy, much related to the personal image or self esteem. **SPS (subjective probability of success)** shows the extent to which a person expects to successfully perform a given task (Eden, 1988).

People who are given a task for which they are not trained or educated create a lower expectancy on their performance than if they would feel confident in their task. This creates smaller attempt to perform, meaning training is crucial to boost performance, not only to improve skills but also increase trait expectancy among the workers.

Difficult goals are related to increased performance expectations but when it comes to SPS it should be noted that it will decrease as goals get more and more unattainable. Preferable would be to aim for a fifty-fifty chance of success in performing a task (Eden, 1988). This can be adjusted by changing the design of a task or by changing the self expectancy of the executor.

To conclude, it is important to continue to perform productivity analyses mainly in order to force one self to define the goal one wishes to achieve and to find what the limiting factors for this are. If, as in many cases, labour performance proves to be one of the limiting factors the tool of assigning appropriate goals to the worker through expectancy and state expectancy is a cost efficient way of doing this.

Higher goals can be forced upon the employer, which in most cases increase productivity as such. Another way is to affect the employee´s mindset on what he/she is capable of doing. Combined with increased official goals, increasing expectancy among employees has the same effect as simplifying tasks for them. There is however always a limit to how high goals can be set before they are perceived as unattainable by the employee and thus result in decreased expectancy.

10. Improvement and development work at Tetra Pak

Improvement work is a large part of all companies. In this Master Thesis connected to Tetra Pak the focus has been put on WCM (World Class Manufacturing) and RA (Risk Assessment) methods because these are methods used by Tetra Pak that are closely connected to and involve the operators and employees throughout the development processes.

10.1 World class manufacturing

At Tetra Pak, World Class Manufacturing (WCM) has become the standardised way to work to remain competitive and all Tetra Pak factories all over the world are implementing the same structured program (Underleverantören, 2005).

The term WCM was originally coined in 1984 by the two business professors Hayes and Wheelwright. The working approach had however emerged in the United States already in the 1970's, as a mean to stay competitive against the advancing ideas of the Japanese market, where many of the ideas were born (Hopper et al., 2007).

At Tetra Pak WCM has become the Tetra Pak way to work with originally Japanese TPM methodology (Total Productive Maintenance). This methodology, which emphasises the importance of people, has then been adjusted to suit Tetra Pak (Imants BVBA, 2009; Interviews). One of the main goals is to avoid unnecessary work by documenting and then standardising experiences and best practices, to promote factories to learn from each other (Underleverantören, 2005).

At Tetra Pak each factory has a WCM coordinator that coordinates the improvement work. Cross-functional development teams, called pillars, support the production organisation with data gathering, loss analysis, and education of the methods. The pillars allow people from different factories to share their experiences when faced with similar issues. The most common pillars are focused on improvements, costs, quality improvements, safety and autonomous maintenance. The purpose is to identify all losses within the pillar areas and minimise these using standardised methods. By repeating the methods over and over again the improvement process becomes automated and less effort has to be put to choosing approach and more on solving the identified issues. And the WCM work has given results: For example did the number of accidents decrease by a third during the Safety pillar's first year; complains have decreased by almost 50% and the machine efficiency increased by 25%. But the numbers quickly get old and new issues are constantly identified and new improvements implemented.

The following method examples are of WCM methods that are used at Tetra Pak factories and are relevant for improvement work for operators.

10.1.1 Continuous improvement work

Kaizen is a Japanese word for improvement and when a company adopts the Kaizen model the goals is to improve its processes in small but just as meaningful ways. Kaizen was introduced by Toyota in Japan in the 1950's and has since then become one of the major reasons that Japan has become one of the strongest industrialised countries. Kaizen is about finding small possibilities for improvements by continuously solving issues. Compared to the traditional western view where innovation is the goal and

improvement are done in larger steps after the implementation of each solution, the many small improvement steps through Kaizen increase quality on a continuous linear scale, see figure D.9.

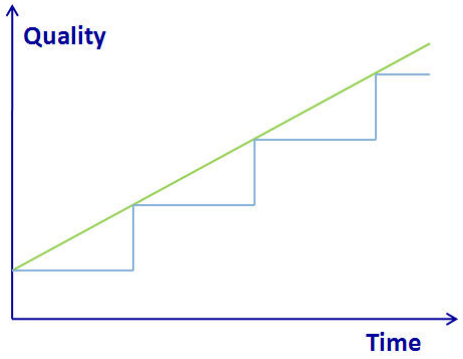


Figure D.9 Improvement steps through continuous Kaizen work (linear) compared to the western view (steps)

At Tetra Pak issues are often solved by using **Cause-effect diagrams** and the **5 Why** method. The Cause-effect diagrams are used as a way to guide the discussion towards finding the causes of issues before trying to solve the problem, see figure D.10.

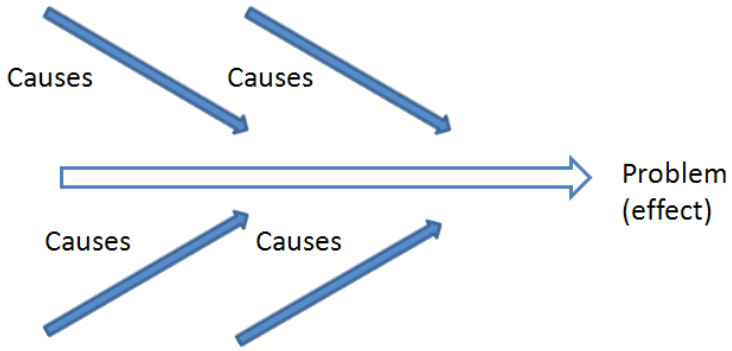


Figure D.10 Illustration of a Cause-effect diagram

The causes can be grouped in different ways and one way to do it is using the Kaizen concept called the 4M. This approach facilitates including all aspects when investigating a process. The amount of Ms and their significance sometimes differ but Tetra Pak uses the 4Ms given in table D.7.

Table D.7 Description of the 4Ms

4M	
Man	Includes how the operators perform their tasks and operator characteristics such as skills and motivation.
Machine	Involves how the machines are running and how they are designed, e.g. structural weaknesses or fatigue.
Material	Concerns the material flow functions, e.g. if buffers are needed in the process, or

	issues such as defective material or problems related to consumable materials.
Method	Related to the use of standardised methods to make sure all steps are executed correctly. Here causes can be that procedures are missing or incorrect.

The problems are solved in WCM teams including members from both the WCM pillars and the different operator shifts, using the 5 Why method. A more descriptive name of this method is 5 Why Analysis which also indicates how it is used. By repeating "Why?" approximately five times the real root cause can be identified (Interviews).

10.1.2 Autonomous Maintenance

Autonomous maintenance (AM) is one of the pillars most directly connected to the operators. The goal here is to create a sense of ownership between the operators and their machines. The major responsibility to maintain and improve the machines should be on the operators and not on a separate maintenance team.

According to literature AM is a critical first step of TPM. The AM pillar emphasises the importance of the machine operators and since the operators are close to the machines most of the time they should also be the first to identify any abnormalities. To do this the operators should be trained to close the gap between them and the maintenance team. AM has seven steps that should be implemented to progressively increase the operators' knowledge, involvement and responsibility for their equipment, where the ultimate goal, step 7, is autonomous maintenance. The goal is to create a safer working environment where the operators experience a sense of pride and ownership of their machines. This will also lead to fewer breakdowns, defects and other losses (Imants BVBA, 2009).

10.2 Risk Assessments

In complex systems there are many different types of possible system errors to consider. At Tetra Pak risk assessments (RA) have been incorporated in the required working procedure. It is recommended that the RA is performed by a team with different backgrounds and expertise to be as thorough as possible. According to TP standard (Jaretun, 2009) the team should include team members with knowledge about technical issues related to the machine functions, experience of the machine operations, accident history of the machine under investigation and finally someone with good understanding of regulations and standards, additional safety issues and human factors.

The RA should consider all uses of the machine, i.e. all persons who interact with the machine at all life phases. To do this all "reasonable foreseeable misuses" need to be identified, which requires studying the relationship between actual use and recommended procedures. Human error is one of the topics mentioned to be considered but no standardised recommendation on how to do this is suggested.

According to the Tetra Pak Standard multiple RAs should be performed throughout the design process, starting during the design phase, repeated when the design is finalised, when a prototype exists and when the machine has been implemented. Additionally, RAs are done if a machine is modified or if mishaps or malfunctions indicate that something is not right.

E Methodology

Methodologies are systematic approaches to reach certain goals. They are used to structure work in development and research and to secure the quality and validity of any work. In this chapter the chosen methods for this Master Thesis study and modifications and decisions that have been done are described. The actual process of data collection will also be explained in detail.

1. Overview

In the previous chapter methods used for data collection in this Master Thesis were described. In this chapter the reasons for choosing certain methods are outlined together with a description of how they were used in this study. Confines and assumptions that are of importance are also presented here.

The actual process of collecting the needed information took up a large part of the Master Thesis project. The data collection process has been divided into seven sub-steps that required different methods. The steps are listed below:

1. Easy ITS data collection (unstructured interviews and observations)
2. Study preparations
    a. Lund pre-study (unstructured interviews and observations)
    b. Education material
3. Limburg study (semi-structured interviews, unstructured interviews and observations)
4. Lund study (unstructured interviews and observations)
5. Validating Existing Pre-press SHERPA (semi-structured interviews)
6. Validating Easy ITS SHERPA (semi-structured interviews)
7. Additional interviews with WCM team, ergonomist, shift managers, etc. (semi-structured interviews)

A very large amount of data was gathered throughout the process and therefore it was important to structure the data so that it could be analysed and presented in a proper way. The data will be structured in task analyses that will be the base of the human error identifications. Preventive measures and remedial strategies will be based on the human error analysis and suggestions from operators, management and brainstorming. These suggestions will be complemented by theories from literature.

2. Methods for Data collection

When defining a study it is very important to use methods that are appropriate. What makes a method appropriate depends on several factors and a range of these will be outlined in this chapter. By following these criteria and discussing them in relation to the Master Thesis study appropriate methods can be chosen. The chosen methods for data collection are presented together with requirements based on study execution.

2.1. Criteria for method selection

In table E.1 six criteria to consider when selecting a method are outlined and the characteristics of the Master Thesis study are described.

Table E.1 Criteria for method selection

Criteria for method selection	
Questions	The purpose of this Master Thesis is to predict and solve operator difficulties on an early stage in a development project. The core is a human reliability assessment where preventive measures are suggested for the implementation of the Easy ITS project. To do this, the process together with the different operator tasks and experienced issues, need to be fully understood.
Context	The Easy ITS project is still in an early stage and has not yet been implemented. In early stages machine investigations could be done by performing experimental studies but to get an idea of the natural human machine interaction, the existing process had to be studied instead. By studying existing ways it is possible to do in depth evaluations. The context of interest is the working tasks taking place in the Pre-press production line in a factory building.
Data type	The study will focus on possible errors and risks for accidents and therefore the collected data is mostly qualitative. Parametric data to perform statistical tests will not be collected in the study but the product of the human error analyses will partly be quantified to be visually presented and more easily comparable.
Available resources	A large proportion of this Master Thesis has been dedicated to the study and with complementing validating interviews the data collection continues throughout the project. Today 42 plants exists producing packaging material with Tetra Pak equipment and the goal has been to select a representative sample to be able to draw conclusions that can later be generalised. Two different factories, one factory in Lund and one in Limburg, were investigated in the study. On each site the possibility to view the everyday work process was needed along with access to personnel and management. Language barriers proved to be another limiting factor and translation support was needed since English was not spoken by everyone at the factory in Limburg.
Access	The sample chosen depends on which sites are available for investigation and the relationship between the project and those sites. Additionally the study had to be carefully planned to minimally disrupt the production. Getting access to people for

	longer interviews conducted away from the production facilities was another issue. In Limburg interviewees were appointed by the management and in Lund the operators within a shift were asked if someone wanted to participate.
Expertise	Different levels of expertise are needed for different methods. Theories described in the Theoretical framework function as the knowledge basis. To perform the interviews, knowledge about the process and observations knowledge about what to look for was crucial and thus needed to be gathered beforehand. For general ergonomics the company ergonomist was interviewed.

2.2. Conclusion regarding method selection

Since the human-machine interaction is the area of interest the existing production line had to be studied to work as the base for predictive analyses of the Easy ITS process. Based on the criteria, compiled above, the most suitable method for this study has been proven to be a combination of observations and interviews.

Questionnaires, that could have been a functional alternative, were considered not to give enough in-depth data. Questionnaires focusing on ergonomic issues and specific opinions could have been used, but as a large part of the collected data regarded the process steps, immersing in the production was considered to be of great importance. Furthermore, observations were valuable since there was access to the actual production sites.

The task steps will be studied through observations on two different factory sites. Observations seemed like the most appropriate option since they, if conducted well, result in objective data and give real life insight to a topic. Two sites with different production methods are considered to be sufficient to get generalizeable data. To prepare the observations and to get out as much of them as possible pre-studies were done. This was especially important before the scheduled observations in Limburg because the time there was limited. Beneficial for the study was the long-term access to the factory site in Lund, where question marks could be answered continuously. More information about the observations is found below.

To complement the observations, personal interviews were chosen; unstructured interviews during the observations and more structured ones separately. This gives the opportunity to go into depth on aspects that have been found especially interesting and also to have conversations in an environment where the workflow is not disturbed. Issues and difficulties that are hard to detect during observations will be investigated and discussed during the interviews along with more general factors affecting the operators' working environment. More information about the interviews is found in table 11.

Additionally data in written form will be collected and studied as a mean for preparing observations and interviews and to clarify question marks about the process after the study.

2.3. Observations

In order to perform the observation in a satisfying manner several requirements needs to be fulfilled. Table E.2 gives a description of how each requirement was handled.

Table E.2 Observation process requirements

Observation process requirements	
1. Define study requirements	Access to both locations is needed. Some prior knowledge of the process is crucial to be able to ask appropriate questions and understand what is observed and what actions deviate from proper task execution.
2. Define scenario observed	The scenario observed will be real life observation. More specifically it will be a regular working day at a Pre-press production line at several different sessions including morning, afternoon and night shifts. In Limburg an initial task analysis, based on the pre-study of the process in Lund, was used as a basis. This was efficient during the observations since deviations could be noted instead of all process steps and it also indicated what should be observed. During the study in Lund updated task analyses and the human error analyses under development were used.
3. Design observation	When conducting the observations two observers will be present, observing several operators performing their work tasks. Preferably the two observers can observe different situations simultaneously. Clarifying questions will be asked during the observations. Initially the observations will be unstructured to get an overall knowledge about the working tasks and the general working environment. On later occasions a more structured approach can be used since the observations then can follow the gradually defined task analyses.
4. Conduct pilot session	Due to the closeness and availability of the Lund facility, introductory sessions are performed to ensure that correct preparations have been made for the observations performed in Limburg where the time period is limited. During the pilot sessions it was experienced as sufficient to take notes using pen and paper and not use a video recorder.
5. Conduct observation	Initially a brief presentation of the Master Thesis work should be done to all shifts to let all operators know the purpose of the visit and discussions. The observations were performed on multiple occasions (see below for a more thorough description). Notes are taken using a notepad and a pen.

6. Data analysis	After each short observation session notes are transcribed and issues of special relevance highlighted. The collected data will also be used directly to modify initial task descriptions. As two observers will be present during the observations the notes from both may be compared to ensure that interpretations are correct. To do this, transcribed data is studied and adjusted by both observers in retrospect.

2.4. Interviews

In order to perform the interviews successfully the different stages of the interview process have to be defined and several requirements need to be fulfilled. Table E.3 gives a description of how each requirement was handled.

Table E.31 Interview process requirements

Interview process requirements	
1. Sampling	The interviewee sampling for the different interviews varied. The goal was to talk to operators from different shifts and at least one management member on each site. In Limburg structured interviews were done with three operators, two from the Cliché department and one from Mounting. It was preferable to talk to operators from different shifts to identify a range of working methods and issues. In Limburg the operators were chosen by the management which might have had implications on the results (see Discussion (I:2)). For the unstructured interviews operators from all shifts were approached on multiple occasions. Naturally some operators had more to say and were more interested in participating. In Lund two operators from each department participated in the structured validation interviews. The operators came from different shifts, had differing levels of experience at Tetra Pak, and of different gender. These interviews were scheduled by asking for participants when visiting two of the shifts. Additional interviews for data collection were done with one of the shift managers in Lund, two WCM team managers and an ergonomist.
2. Obtaining an interview	The unstructured interviews were conducted during normal working conditions but to get the operators' full attention and a more relaxed environment the structured interviews were performed away from the production area. To make this possible, shift managers were approached both in Lund and Limburg who allowed operators to leave production and suggested facilities for the interviews to take place in.
3. Designing the schedule	The interviews will be semi-structured, meaning some questions will be prepared beforehand. This also gives an opportunity to adjust the amount of questions to suit

	the personality of the interviewee. In Limburg a list of interview questions were prepared and sent to the management beforehand. This list was then mostly followed but there was still the opportunity to go deeper into subjects that turned out to be of interest. Since the questions were written before the observations in Limburg some updates had to be done. There were some variations among the questions asked to the operators and the production manager. The questions can be found in the Appendix (K:1.2). The validating interviews in Lund were done based on the filled out human error analyses (SHERPA), see D:7.4. The goal was here to see how likely errors identified during observations and unstructured interviews actually were and if anything had been overlooked. To make sure the time limit was kept the interviews focused on question marks and tasks defined as critical.
4. Asking the questions	During the validation interviews one respondent and two investigators were present. The decision to include only one respondent was made partly because access to respondents was limited. Also, it was important that the interviewees were not affected by anyone else's opinion and that they felt free to speak their mind, knowing that the interview would be anonymous. In Limburg members of the management team were present during the interviews; this can possibly have affected the data. In Limburg the questions had to be translated into German which limited the spontaneity and the possibility to ask follow-up questions. Since possible difficulties already had been defined when conducting the validating interviews in Lund it was very important to remain objective when asking questions about the tasks.
5. Recording the response	The interviews were recorded by taking notes, which created a more relaxed atmosphere than using a dictaphone or video recorder. Additionally the semi-structured interviews in Lund were done on multiple occasions and often in connection to the observations, and here using recording devices would likely have been limiting.
6. Analysis	Directly after the interviews the collected data was transcribed with more details and full sentences. This was done to avoid forgetting information and making interpretations. Rewriting all the information was time-consuming but confirmed that the interview answers were interpreted similarly. Using written notes was also more efficient than having to transcribe audio and visual recordings. The data was then analysed using task analyses and human error identification methods.

3. Data collection process

The main characteristics and planning of the data collection have been described in table E.1-3. However, data collection took place at several states in the project process and those different steps will be outlined and described separately in this section.

3.1. Easy ITS data collection

In the beginning of the project it was crucial to get an overview of the new process in order to define a scope for the project and to choose appropriate methods. Without the knowledge of what differed between the two processes, a project purpose and scope would easily be incorrectly stated.

Data was collected through unstructured interviews with members of the development team and there were possibilities to observe the equipment in use. The information collected during these interviews was translated into an initial task analysis.

For several reasons the new production process was altered along the way resulting in changes to the equipment. This created a need for several updates of the task analysis during the duration of the Master Thesis. After several alterations it was decided to leave the completion of the task analysis of the new line to as late in the Master Thesis process as possible.

3.2. Study preparations

3.2.1. Lund pre study

As mentioned, it was necessary to understand the technical process to be able to identify differences and local solutions. To facilitate the Limburg study this had to be done in Lund prior to the Limburg visit. This pre-study consisted of unstructured interviews and observations during the different production shifts. The information was structured into initial task analyses that were updated later in the study. This information was also the basis when designing the interview questions for the interviews in Limburg.

3.2.2. Education material

In order to get an overview and deeper understanding of the existing process, education material for Pre-press was studied. This was helpful for several reasons, both in trying to understand more complex tasks, such as sorting and mounting, in more detail and to give insight to what the procedures looked like further back in time. Furthermore the education material gave an indication about if how the operators actually executed the tasks deviated from recommendations.

The education material was produced for tasks that were causing most issues and done as a part of the WCM work, which gave further indications on where to focus the analyses and helped to clarify the process steps when structuring the task analyses.

3.3. Limburg study

In Limburg time was a strong limiting factor which forced a more structured data collection. Preparations were made in terms of preparing a list of questions for operators and management personnel, see *Appendix* (K:1.2). Also prepared was the task analysis from the pre-study done in Lund that facilitated observations and creating a corresponding task analysis of the process in Limburg.

First observations and unstructured interviews similar to those in Lund were used to get a good overview of the analogue cliché making process and how it differed from the digital process in Lund. Observations were done during both day and night shifts to get an insight to how shifts differ. Semi-structured interviews were done with two operators, chosen and approached by the Pre-press manager, and also one with the production manager himself. The interviews took approximately 1-1,5 hours each and were semi-structured, leaning more towards structured than those done in Lund.

A limiting factor in Limburg was the language barrier. The interview with the production manager was done in English and therefore no third translating part was needed. To note is however that English was not the first language of either parts. For the interviews with the operators a translator was used which likely affected the interpretation of the answers and questions since there was yet another person needing to do interpretations. Language barriers can also limit discussions and to that not all is said because of the extra effort needed to explain one self.

3.4. Lund study

In Lund data was collected through unstructured interviews and observations during approximately 10 visits to the Pre-press production department. Since Lund is run with rotating shifts a majority of the seven shifts were interviewed and observed. During the visits and unstructured interviews most operators were approached and often on multiple occasions, but naturally some operators had more things to say and were more interested in participating.

The focus of the observations varied during the data collection process. Some observation were done to get an overview while some focused more on specific parts of the process that either created question marks or gaps in the task analyses or tasks that were discovered to create issues for the operators.

3.5. Validating existing Pre-press SHERPA

When all interviews had been transcribed and the data analysed and presented in a SHERPA, the SHERPA was worked through during feedback sessions together with operators to secure that unclear issues were interpreted correctly and that conclusions could be said to represent the user population in general.

The feedback sessions were carried out by a total of four interviews with operators from Lund Pre-press, two operators from Cliché Making and two from Cliché Mounting. Four different shifts were approached and the operators that volunteered were interviewed for approximately 1,5 hours each. Two female and two male operators were interviewed who all had different backgrounds at Tetra Pak. The interviews were carried out away from the production area to be undisturbed.

In the feedback sessions the task steps structured in the SHERPAs were worked through and tasks identified to be more critical were discussed. Tasks already identified in the unstructured interviews to have a low validity were discussed if any uncertainties remained. Additionally some new information and improvements had been made to the process since the beginning of the study which is included in the report.

3.6. Validating New line SHERPA

Feedback sessions were carried out also in the Easy ITS development project. Two team members were consulted on the outcome of the Easy ITS SHERPA to the extent that the most critical issues were discussed and the interviewees were given the chance to mention new possible errors.

3.7. Additional interviews

Additional interviews were conducted with WCM team members, a shift manager and Tetra Pak's ergonomist. These interviews were between semi- and unstructured. The first two interviews concerned Tetra Pak's improvement work and the data is presented in the *Results* section (F).

The interview with Tetra Pak's ergonomist was conducted as a evaluation within the Easy ITS project to get expert opinions regarding machine evaluations. This input is primarily presented in the appendix 4 (*In depth study: Manual Handling)*, and as additional input to the SHERPA.

4. Methods for data analysis and data presentation

The collected data is presented in hierarchical task analyses and Human error identification analyses. The chosen Human error identification method is SHERPA, Systematic Human Error Reduction and Prediction Approach. More information about these methods can be found in the *Theoretical framework* (D:7).

During the data collection process information that could not be included in the SHERPA was also gathered. Examples are insight to how the company works with development, comments on shift work, to what extent productivity goals are achieved and other latent issues the operators are experiencing. This information is given and discussed in the end of the *Results* section (F).

4.1. Task Analyses

The concept of creating a task analysis is described in the *Theoretical framework* (D:7.3). Since the Master Thesis incorporated several different production steps, it was very important to find a sufficient level of detail to construct the task analysis. Initially it aimed at a level that was possible to collect information on during the shorter visits to the production and during the development of the project an appropriate level naturally developed when considering both time limitations and what level of detail could actually help detect causes of human errors. Since the existing and future processes differ quite a lot in the end, it would not be justifiable to go into more detail to find relevant issues and solutions.

By using different sources the reliability of the task descriptions are much improved. For some parts of the task analyses it was possible to compare operator interviews with both education materials and to other operators' descriptions of how a certain task is carried out. For this reason the task analysis constructed for the Lund Pre-press department is more reliable than the one created for Limburg. It should also be said that the way a task is carried out differs between individuals. Size, strength or even preference affect how operators choose to perform tasks and this is not necessarily a violation of given directions. For the Master Thesis however, the directives given in education material are used primarily in the task analyses to make sure already given recommendations and solutions are not given again.

Many details of the Easy ITS process will not be decided before the Master Thesis is completed and those question marks are dealt with in different ways, depending on what is possible and appropriate. Primarily the development team is questioned and if possible a decision is made on how that certain issue will be approached. However, it should be said that due to the constant development and dynamics of the development project the process design will still change in many ways.

4.2. Systematic Human Error Reduction and Prediction Approach

The Systematic Human Reduction and Prediction Approach procedure (see D:7.4), will be followed. The SHERPAs are used to identify issues but also to compare the different processes. To suit the studied work process a range of assumptions and adaptive actions were done. The study performed was extensive and large amounts of data were collected. If all assumptions are clearly defined this highly improves the intra-reliability of the method.

Task and Error descriptions

For each task descriptions of possible errors are added. Many of the errors were taken from interviews and discussions. For other tasks the authors separately filled out errors they could think of and the consequences of those errors were described with the use of the knowledge of the process. Since the analysis was validated through interviews the validity is considered to be sufficient.

When creating the Easy ITS SHERPA the tasks and errors that resembled those of the Pre-press line were transferred directly. For many of these, consequences, recovery and remedial strategies needed to be adjusted, for example many of the remedial strategies in the Pre-press SHERPA referred to recommendations from specific education materials developed for the existing process. Tasks that were not very similar to those of Pre-press could sometimes still be used since they involved handling of the same material. For remaining tasks errors were added by using several means; members of the development team were consulted on possible errors through several shorter discussions, experience from interviews with Pre-press operators were used by the authors to predict possible issues and finally rational thinking and brainstorming. Since the analysis was validated through interviews the validity should be sufficient.

Alternative solutions have been discussed with the Easy ITS team throughout the Master Thesis. In the SHERPA these solutions have been set as remedial strategies rather than already implemented in the work process. This is to emphasise the need for the extra effort to implement these changes. In the final stages of the analysis the total criticality of the Easy ITS process is calculated and compared for some of the suggested solutions (see G:3).

Consequences

Creating the task analyses gave the authors valuable knowledge and insight to the different processes crucial for creating and filling out the SHERPAs. Consequences of the errors were identified through interviews and education material often gave motivations for why they should be used.

Recovery

Recoveries used in this project included the following:

- *None*, meaning there is no possibility to avoid the consequence created by the error.
- *Immediate*, meaning that the consequence of the error can be avoided already in the following task.
- *Task X*, implying that the consequence of the error can be noticed and avoided while performing task X.

To be able to identify the recovery the goal has to be clear. One issue that occurred along with the work process was how to deal with recovery possibilities when the consequence involved time loss or that an error was simply marked as an unnecessarily time-consuming action. For example if a machine was not started it would probably be started later since the operator would notice it had not completed the job. Two consequences occur from this error: the job is not done and time has been lost. The fact that the job has not been done can be saved by simply starting the machine whereas the time lost can never be regained. Since time is a strong factor in this production process the recovery will be set as *None* in cases that cause time loss.

Probability

For general recommendations the probability assigning is described as follows:

- *Low probability (L)* - errors never known to occur
- *Medium probability (M*) - errors known to have occurred on previous occasions
- *High probability (H)* - errors known to frequently occur

Errors that were brought up by the operators during interviews were given medium probability if it had only occurred on a few occasions. Errors that they experienced to occur at least a couple of times a month were given a high probability. Errors were given low probability if the operators did not consider them to be an issue.

Criticality

Criticality of the error was rated in two levels: either an error was set as critical (!) or not ( ).

In this study errors with a high probability (H) are always marked as critical even if the consequence is not very serious. This is because the issue still has a large negative impact on the work process due to its frequent occurrence. In the same way a critical consequence together with a low probability (L) are not likely to be seen as critical and thus not labelled as critical either since the impact on the process is very small. However, if the consequence is extremely severe even an error with low probability should be set as critical. For errors with a medium probability (M) the consequence was the deciding factor and for example errors that could lead to physical injury was most often rated critical. However, it should be emphasised that this categorisation sometimes was subjective which affected its reliability.

Remedial strategies

In a SHERPA there is little room to elaborate possible issues and recommendations, although the method facilitates coming up with concise recommendations. For smaller issues it may even be beneficial because sometimes it is the smaller solutions that make a work process more efficient.

For a deeper analysis, the most critical errors and consequences are discussed in the result section and the ones found to be most critical for the Easy ITS are further investigated in the *In depth analyses* to give appropriate and usable solutions (H).

Additional comments

Latent and *ergonomic* issues have been added to the error mode categorisation. This is done because these issues are not actively performed by the operators but still highly influence the operators' work tasks. The errors set as ergonomic (Erg) are mostly related to manual handling. The tasks these errors are related to can also be facilitated by improving the process and thus they were considered important to include. Latent issues are often related to previous task steps in the process. They were relevant when considering how the work process as an entirety could be improved rather than simply focusing on one small step at a time.

It is crucial to be consistent when assessing weighed values/labels such as criticality and probability and therefore a constant comparison between the different SHERPA's took place to make sure that similar errors and consequences were graded in a consistent manner. Additionally by comparing the different processes between each other the use of the method was further extended.

4.3. Quantification of data

Quantified data is often easier to present and more accessible and therefore favourable when presenting results in a large company where much information is communicated daily. The data from the study was quantified to illustrate the comparison of the existing Pre-press processes to each other and to the Easy ITS process.

The number of critical issues was compared both within processes for the different tasks and between the different lines. This was done by presenting the number of critical tasks in the different parts of the processes. The critical issues were also separated into ergonomically related, given the error mode *Erg*, and issues resulting from a human error action. This way it is possible to get an indication of what types of difficulties the operators are experiencing or will experience with the process and how these can be prevented.

The objectivity of the compared data can be ensured for two reasons. Firstly, the rankings have been done as objectively as possible and the grading has been done by the two authors separately and unclear issues discussed further, especially for the most critical errors. Additionally critical and frequent issues were thoroughly discussed during the feedback interviews to make sure the information had been interpreted correctly. Secondly, since the same procedures and methods have been used in all investigations, inaccuracies resulting from the analysis are hopefully done equally in all comparisons and hence should not significantly influence the end result. The authors therefore believe that the validity of the quantifications is sufficient to be able to draw applicable conclusions.

However, these quantifications will be viewed solely as a complement to the executed error identification that is one of the main deliverables in this Master Thesis. The quantification functions as a mean to illustrate the results from the SHERPAs and can hopefully raise an interest for the rest of the analysis.

F Results - Current situation analysis

In this chapter the issues within existing Pre-press are outlined for both Lund and Limburg. For each step a summary of issues are presented with a main focus on reoccurring and/or issues rated as critical in executed SHERPAs. Mentioned difficulties are based on executed interviews, observations and human error analyses, which are described in the methods chapter. Ergonomic issues and latent errors, not normally covered by the SHERPA technique, are also mentioned for the relevant process steps. Additionally, detected remedial strategies that can improve the task execution are summarized for each process step.

For a complete process description, with in-depth descriptions of tasks, issues and remedial strategies for each task, see appendix 1 (Process description: Pre-press). The task analyses and the detailed SHERPAs are found in appendix 5 and 7.

1. The Pre-press departments

The mounted clichés, manufactured in the Pre-press department, are produced through the cooperation of several departments within Tetra Pak, and before an order arrives to the production site it travels via a number of instances.

The production planning is based on orders arriving to *Customer Sales Representatives* that gather all orders worldwide and distribute and assign them to the different Tetra Pak factories. The orders are then sent to production through the computer system *P2*. In the *Customer Folder Archive*, production orders, including reference print-outs, are archived and prepared. The files needed for imaging and reference print-outs are provided by the *Digital Files office*. These activities are described in more detail in appendix 3 (*In depth study: Sorting).*

When an order has been prepared it is time for it to be manufactured, which is done in the *Cliché Making* and the *Cliché Mounting* department. In this study *Cliché Mounting* is divided into *Mounting preparations* and *Mounting*.

1.1. Lund Pre-press

Cliché Making, the first Pre-press department, includes all tasks for creating a fully processed and cut cliché. To create the pattern on the printing plate, the Lund factory uses a digital process; see *Process Technology* (C) for a more thorough description. Shortly, in a digital process the plate is prepared with a black top layer which is removed using a laser. The plate is then exposed with light to harden the polymers. To keep the plate together when the unexposed polymers together with the black layer are removed, the plate is also exposed from the other side, creating a so called floor. After processing the imaged clichés are cut out, using an automatic cutting machine.

In Cliché Mounting the clichés are sorted and mounted onto sleeves. The sleeves have different diameters depending on the size of the décor. To attach the clichés to the sleeve, the sleeves are first

covered with tape. Today clichés are mounted manually using mounting machines with cameras to help place clichés correctly onto the sleeve.

The two different departments have different shift schemes and there is no job rotation between them which creates a clear separation.

1.2. Limburg Pre-press

Limburg Pre-press is also divided into two departments. The main difference between Limburg and Lund is that Limburg uses an older way of producing cliché decors, an analogue process. In the analogue process there is no black layer on the plate, instead negative films are placed on top of a plate before exposing. The plates are also exposed on the backside to create the floor. Processing, drying and light finishing is the same for both processes but in Limburg a manual cutting machine is used.

The Cliché Mounting department in Limburg uses the same mounting machines and the same taping principle as Lund but in Limburg the sleeves used are slightly compressive and therefore a thinner tape is used.

In Limburg the different departments have the same shift schemes which enable job rotation and helping out between the two departments.

2. Process description

Through the executed human error identification analyses, error possibilities, error consequences, recovery possibilities and remedial strategies are identified for all process steps. Additionally the probability and criticality of each issue is considered. In this section the issues rated as critical and/or are reoccurring are outlined together with suggested remedial strategies.

The interested reader is recommended to also read appendix 1 (*Process description: Pre-press*), where each process step is thoroughly described in the form of task description, summary of common and/or critical issues and remedial strategies for minimising the consequences of those issues. Additionally each department section includes a visual representation of the hierarchical task analysis produced as a basis for the evaluation.

2.1. Cliché Making

Cliché Making includes a number of processing steps, both manual and machine based. Figure F.1 functions as an overview to illustrate how the nine operator tasks are combined. In appendix 1 (*Process description: Pre-press*) each task step is illustrated separately. The numbering used in the hierarchical task analysis is also used in the process descriptions.

1. Plan plate layout
2. Back exposure
3. Imager
4. Main exposure
5. Processor

6. Dryer
7. Light finisher
8. Cutting machine
9. Sort cut plates

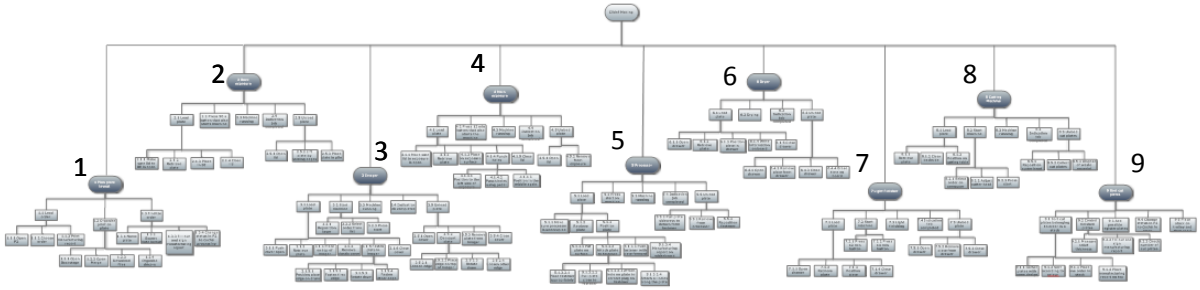


Figure F.1 Hierarchical task analysis of Cliché Making in Lund

1. Plan plate layout

The layouts of the plates are planned by placing a number of décors on each large plate.

Identified issues

- Setting the incorrect status in the computer program P2 causes implications (risk that order is redone).
- Pop-ups, that cause action delays and leads to irritation, often occur in P2.
- Prioritised orders are missed when identifying orders in P2 due to not reloaded order list or the human factor.
- It takes time to learn how to best combine the décors on a plate but once this has been learned the task is no longer critical.

Remedial strategies

- Only relevant statuses should be available for selection in P2.
- Clear colour coding would improve the P2 interface and make information retrieval and selections easier.
- The use of pop-ups should be minimised.
- Automatic continuous reloading would improve order selection.
- To minimise steps, automatic programming to download and rip correct files should be investigated.

2. Back exposure

In the back exposure plates are evenly exposed with light to create a hardened floor.

Identified issues

- Leaning over the large exposure surface, when handling the large plates, causes discomfort in back and shoulders.
- The plates are stiff and easily breakable.

- The exposure handle is placed high up when the lid is open, which involves ergonomic risks when closing the lid.

Remedial strategies

- A pallet with a supply of new plates, placed close to the back exposure and on the same height, would facilitate loading. The pallet could be placed on a lift to keep the plates on a suitable height at all times.
- Automatic opening of the lid (as in Limburg) would decrease uncomfortable working postures. Additionally it would be a good indication that exposing is finished.

3. Imager

In the imager, the information from the planning of the plate layout is used to treat the black layer of the plate with laser beams.

Identified issues

- Loading causes discomfort due to the height of the imager.
- The plates are stiff and easily breakable.
- The plate décor is very sensitive after imaging and there is a high risk that fingerprints, scratches or dust ruin the plate.
- The laser has to be repositioned before imaging. This is time-consuming and causes irritation since the task is experienced as unnecessary.

Remedial strategies

- A movable footstool should be provided to improve the working height (available in Lund today).
- A sliding function between the imager and the next machine unit, the main exposure would minimise plate handling. This would decrease both breaking of plates and discomfort.
- The placement of the machines should be improved and distances, space requirements and in and out feed directions should be considered.

4. Main exposure

In the main exposure, the plate is again treated with light, here to harden the polymers that later will create the décor on the paper.

Identified issues

- Punching of the holes, later used for fastening in the processor, leaves waste material, which causes implications if not removed. This issue has recently been corrected.
- Leaning over the large exposure surface, when handling the large plates, causes discomfort in back and shoulders.
- The exposure handle is placed high up when the lid is open, which involves ergonomic risks when closing the lid.
- In Limburg, the lid does not open enough. This forces the operators to adapt an uncomfortable working posture for long periods of time (standing with bent back and neck) when placing the analogue films.

- Analogue process involves higher risk for human errors.

Remedial strategies

- Automatic opening of the lid (as in Limburg) would decrease uncomfortable working postures. Additionally it would be a good indication that exposing is finished.
- Limburg should consider using a digital process.

5. Processor

In the processor the plate is treated with a solvent and brushes remove the unhardened polymer material, leaving only the floor and the exposed reliefs.

Identified issues

- The attaching of the plate using the punched out holes, is time-consuming and includes inappropriate reaching (ergonomic risks).
- If the previous plate is not unloaded, but left on the processor surface, there is a risk that plates will collide.
- If the décor is touched when lifting the plate there is a risk that it is damaged.
- The operators are exposed to a solvent when cleaning the machine and unloading the plates.
- The plates that are highly sensitive after processing but have to be transported through small and turning passage.
- In Limburg the unloading of the plate from the processor have to be done by manually pulling it out, at a less favourable height than in Lund. This includes a range of ergonomic risks and can lead to scratches on the plate.

Remedial strategies

- The machine line layout should be optimised, for example the processor should be close to both dryers and imager.
- Buffer storage should be provided so that the processors always can be unloaded.
- An alternative plate fastening solution avoiding hole-punching and separate fastener should be considered (e.g. a clamp function that also repositions automatically).
- Limburg has developed a homemade table that includes a device for pulling a plate straight out, avoiding scratches on plate and improves working posture.

6. Dryer

In the dryers the polymer material dries after the processing.

Identified issues

- Partly due to a slippery grip, the plates are sensitive and difficult to handle after the processor.
- The top drawers are placed too high. This forces high lifting and adjusting of the plate above shoulder height.
- The bottom drawers are too low. This forces bending of back when placing the plates.
- The older dryer version is preferable since the lowest drawers are higher.
- High pressure on drawers and often all drawers are needed.
- The area around the dryers is narrow and there is little room to move around.

- Due to dirty and sticky drawer surfaces, the possibility to slide the plate in the drawers is limited. This has improved with new dryers.

Remedial strategies

- A footstool is not possible since there are low drawers as well.
- Placing the dryers closer to the processors would reduce plate handling.
- By increasing the number of dryers it would be possible to avoid using the top and bottom drawers.
- Drawers should be continuously maintained.
- In Limburg the same procedure is followed but plates are cut in halves after the processor which facilitates the plate handling. This would not be possible if an automatic cutting table is used later in the process (as in Lund).

7. Light Finisher

In the light finisher UVA and UVC light treat the plates to make them more resistant; the light also hardens the material further. One light finish drawer is placed on top each dryer.

Identified Issues

- The same issues have been identified as with the dryers, except here the drawers are placed too high, especially in the later version.
- Placing the plates is a particularly critical task since the positioning, as it demands precision to avoid creases and is done above shoulder height.

Remedial strategies

- Placing the light finishers on separate tables, i.e. not above the dryers, is a first step towards solving the height issue.
- A footstool is not possible since there are low drawers in the dryers.
- Drawers should be continuously maintained.
- In Limburg the same procedure is followed but plates are cut in halves after the processor which facilitates the plate handling. This would not be possible if an automatic cutting table is used later in the process (as in Lund).

8. Cutting machine

In Lund, the cutting machine automatically cuts along the décor edges on the plate and delivers the finished clichés. In Limburg cutting is done manually.

Identified issues

- Leaning over the table when placing the plates is an inappropriate posture that might cause discomfort.
- The task of adjusting the cutter head before cutting each plate is time consuming.
- The cutter head has to be repositioned before a new plate can be cut. This is time-consuming and causes irritation since the task is experienced as unnecessary.
- The task involves standing for long periods of time, which can lead to discomfort.
- High demand on good visibility.

- High time pressure on this task, especially in Limburg where the task is done manually.
- In Limburg a ventilation drum, causing a draft, is placed above the cutting table, which causes discomfort in neck, back and shoulders.

Remedial strategies

- Rubber carpets should be placed in front of machine to ease discomfort in back.
- The task distribution should be planned to create a mixture of standing, sitting and moving (e.g. rotations within the shift).
- Lighting needs to be sufficient.
- Repositioning the cutter head could be implemented in the machine functionality.
- Height adjustment of manual cutting table should be enabled.
- Avoid placing working area directly under ventilation drum.

9. Sort cut plates

In the sorting task, the operator organises the clichés into order and places them in a pile together with the manufacturing report before handing the pile over to Cliché Mounting.

Identified issues

- For this task there is time pressure and a high need to remain focused.
- The majority of the sorting is done on top of the light finisher. This working height is too high.
- Additional force required to separate sticky clichés.
- The task involves standing for long periods of time, which can lead to discomfort.
- High demand on good visibility.
- Setting the incorrect status in P2 causes implications and there is a risk that the order is lost.

Remedial strategies

- There would be a larger incentive to sort only once if the departments are considered as one.
- Job rotation within each shift should be encouraged.
- Area for sorting should have adjustable height to enable a mixture of standing and sitting.
- Rubber carpets should be provided to ease discomfort in back.
- A light table should be provided to improve visibility when sorting clichés.
- Only relevant statuses should be available for selection in P2.
- Clear colour coding would improve the P2 interface and make information retrieval and selections easier.

2.2. Mounting preparations

Mounting Preparations includes serving the mounting operators with all they need for mounting, i.e. sorting clichés, retrieving sleeves and preparing tape. All tasks in this step are done manually by the operators. Figure F.2 functions as an overview to illustrate how the task steps are combined. In appendix 1 (*Process description: Pre-press*) each task step is illustrated separately. The numbering used in the hierarchical task analysis is also used in the process descriptions.

It should be said that the tasks included in Mounting preparations are very differently distributed in Lund and Limburg. The HTA shown below refers to how the tasks are distributed in Lund whereas in Limburg many of the tasks instead belong to the mounting operator.

1. Retrieve cliché order
2. Sort cliché order
3. Prepare tape
4. Prepare masking tape
5. Retrieve sleeves
6. Finalise order
7. Take out finished sleeves

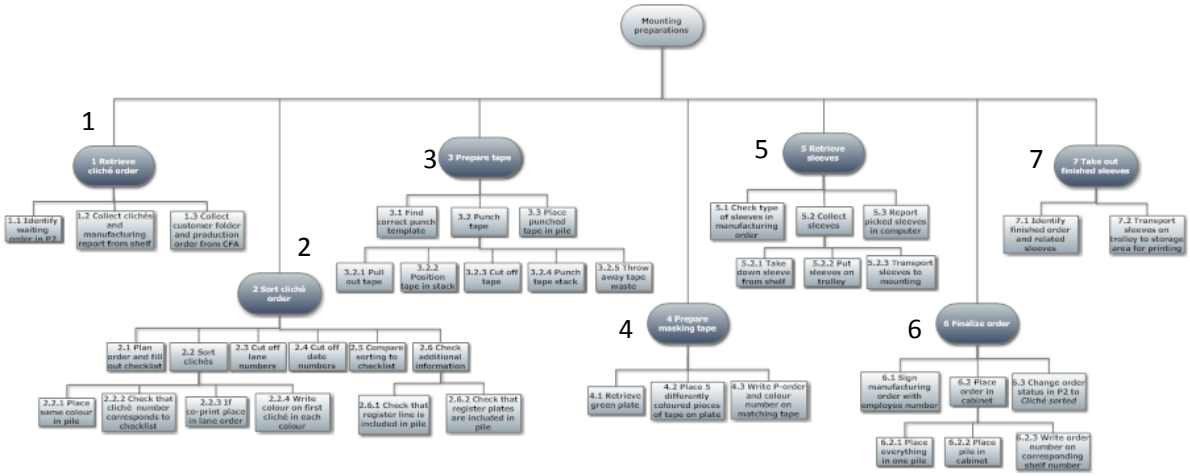


Figure F.2 Hierarchical task analysis of Mounting Preparations in Lund

1. Retrieve order

The clichés with the highest priority are retrieved from the cliché storage to be prepared for mounting.

Identified issues

- Setting the incorrect status in the computer program P2 causes implications (risk that order is redone).
- Pop-ups, that cause action delays and leads to irritation, often occur in P2.
- Prioritised orders are missed when identifying orders in P2 due to not reloaded order list or the human factor.

Remedial strategies

- Only relevant statuses should be available for selection in P2.
- Clear colour coding would improve the P2 interface and make information retrieval and selections easier.
- The use of pop-ups should be minimised.
- Automatic continuous reloading would improve order selection.

2. Sort cliché order

In this step the clichés are arranged in piles, checked and prepared to be mounted.

Identified issues

- High risk of making mistakes when sorting or missing previously done mistakes.
- The task of writing a handwritten checklist is unnecessary and tedious and the space on the checklist is too small.
- Date and lane marks are manually cut off the clichés in this task. There are both risks related to cutting off the wrong numbers and damaging the clichés while cutting.

Remedial strategies

- It should be considered if sorting could be done only once, including an additional check.
- The Information required for sorting should be sufficiently provided on the manufacturing report.
- The use of tongs to cut off numbers has decreased issues. However the information could be added already in the imager.

3. Prepare tape

In this step the tape, used when mounting the clichés, is prepared.

Identified issues

- The punch templates are sometimes skew, which will affect mounting.
- Punching out tape pieces creates a large spill.

Remedial strategies

- The quality of the templates should regularly be controlled and worn-out ones replaced. Often manual adjustments to skew tape can be done when mounting but should not be necessary.
- The need for tape pieces of the same format as the clichés could be questioned and the use of wider tape widths investigated.

4. Prepare masking tape

In this step masking tape with information about the sleeves is prepared.

No critical issues have been discovered in this step and all potential errors have been considered to be of low probability. Nonetheless, the necessity of preparing the masking tape beforehand should be considered in future solutions.

5. Retrieve sleeves

In this step the correct sleeves are retrieved from the sleeve storage.

Identified issues

- Due to high heights and the use of a ladder, there are large ergonomic risks when retrieving the sleeves from the shelf.
- The shafts, on the horizontal trolley, are placed too close, the lower shafts are too low and the higher too high.

- There are large ergonomic risks due to twisting grips and lifts when using the vertical trolley.
- Walking paths and automatic carrier paths are crossing which can cause dangerous collisions.
- The right sleeves are not always available.

Remedial strategies

- The shelf used today should be replaced. A solution could be a rotating shelf system for sleeve storage that delivers all sleeves on an appropriate height.
- Using other trolleys or redesigning existing ones should be considered.
- Carrier paths crossing walking paths should be avoided when planning the factory layout.
- Communication and planning is required when planning sleeve use.

6. Finalise order

In this step the final preparations are done for the order to be ready for Mounting.

Identified issues

- Setting incorrect status in P2 causes implications and there is a risk that the order is either redone or lost.

Remedial strategies

- Only relevant statuses should be available for selection in P2.
- Clear colour coding would improve the P2 interface and make information retrieval and selections easier.
- Additionally it is important that the operator makes sure that all material is added to the cliché pile.

7. Take out finished sleeves

In this step, finished orders are delivered to printing.

See issues and remedial strategies suggested in task 5, *Retrieve sleeves* above.

2.3. Mounting

In this step the operator retrieves what is necessary for mounting and mount clichés to a sleeve on a mounting machine called Microflex. All tasks in this step require an operator at all times. Figure F.3 functions as an overview to illustrate how the task steps are combined. In appendix 1 (*Process description: Pre-press*) each task step is illustrated separately. The numbering used in the hierarchical task analysis is also used in the process descriptions.

1. Retrieve order
2. Load sleeve
3. Mounting tape
4. Mounting clichés
5. Additional mounting
6. Check completed sleeve
7. Unload sleeve

8. Report completed order

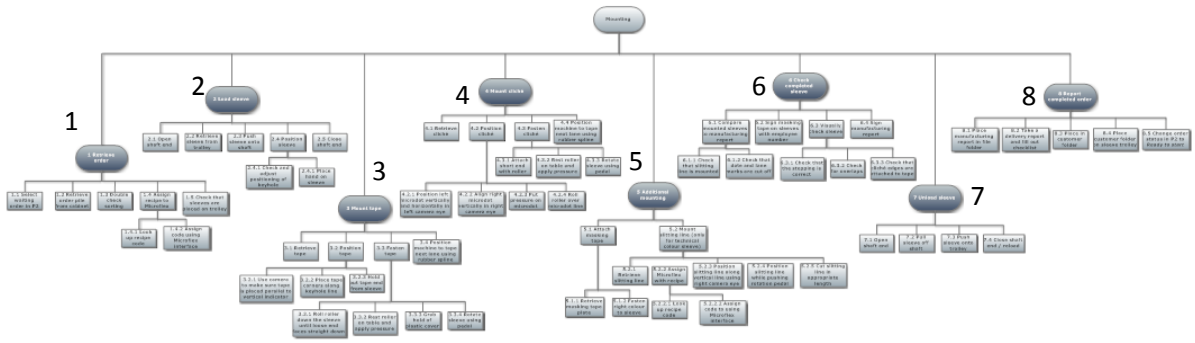


Figure F.310 Hierarchical task analysis of Mounting in Lund

1. Retrieve order

In this step the operator makes the final preparations before the actual mounting begins.

Identified issues

- Prioritised orders are missed when identifying orders in P2 due to not reloaded order list or the human factor.
- Previously done errors might not be detected or the sorting check might be omitted.
- The interface of the Microflex is located above shoulder height which causes a questionable working posture.

Remedial strategies

- Clear colour coding would improve the P2 interface and make information retrieval and selections easier.
- It should be clear who has the responsibility to perform each check.
- The Microflex display should, if possible, be placed further down.

2. Load sleeve

In this step a sleeve is loaded onto the Microflex machine.

Identified issues

- The task of moving the sleeves from the trolley onto the shaft is highly critical.
- The shafts, on the horizontal trolley, are placed too close, the lower shafts are too low and the higher too high.
- It is heavy to push the sleeve onto the shaft, especially if the sleeve is worn out.
- There are large ergonomic risks due to twisting grips and lifts when using the vertical trolley.

Remedial strategies

- It is important to have space when handling the sleeves.
- Using other trolleys should be considered. Horizontal to horizontal lifting avoids twisting.
- The sleeves should be regularly checked and maintained.

3. Mounting tape

In this step the surface of the sleeves are covered with a layer of tape.

Identified issues

- There are risks of air bubbles being trapped under the tape layer.
- Dust and material from roller might get transferred onto the tape.
- The use of the foot pedal to rotate the sleeve causes an uneven working posture.

Remedial strategies

- A standardised working procedure should be provided (e.g. concerning use of rollers)
- More functionalities should be incorporated at waist height (e.g. use rubber spline to rotate sleeve).

4. Mounting clichés

In this step the clichés are mounted onto the sleeve.

Identified issues

- The most critical issues are related to the positioning of the microdots.
- The operators need to be observant and choose the correct clichés to mount.
- The use of the foot pedal to rotate the sleeve causes an uneven working posture.
- In Limburg the positioning to mount next lane is done on the Microflex interface, i.e. above shoulder height, which might lead to discomfort.

Remedial strategies

- Cameras and standardised procedures have been implemented to facilitate mounting (Microflex machines are used and continuous improvements are done).
- A possible solution is to automate this process step.
- More functionality should be incorporated at waist height (e.g. use rubber spline to rotate sleeve).

5. Additional mounting

In this step, slitting line and masking tape are mounted.

Identified issues

- There is a high risk of error when mounting the slitting lines, e.g. not completely fastened, overlap/gap, or asquint mounting.
- The use of the foot pedal to rotate the sleeve causes an uneven working posture.

Remedial strategies

- The slitting line could be included on one of the clichés, or its length could be cut already in the cutting machine.
- In Limburg the mounting operator writes information on the masking tape after mounting. This adds an extra check that everything is correct.
- More functionality should be incorporated at waist height (e.g. use rubber spline to rotate sleeve).

6. Check completed sleeve

In this step the sleeve with mounted clichés is checked.

Identified issues

- If previously done mistakes remain unnoticed they might cause short-stops in printing.
- Since the checking tasks are time-consuming and difficult to motivate, there is a large risk for relying too much on others and therefore omitting the task.

Remedial strategies

- Clarify who has responsibility for the quality of the end product, e.g. when signing masking tape or report, and clearly define number of required checks.

7. Report completed order

In this step the completed order is reported and paperwork handled.

Identified issues

- Setting incorrect status in P2 causes implications and there is a risk that the order is either redone or lost.
- The paperwork in this task is time-consuming and there are risks for errors.

Remedial strategies

- Only relevant statuses should be available for selection in P2.
- Clear colour coding would improve the P2 interface and make information retrieval and selections easier.
- Paper forms used should be looked through and unnecessary information should be removed.
- The possibility to connect paper forms to P2 should be investigated, e.g. that all necessary information have to be entered before the order is sent to printing. (Note: Information on paper is sometimes preferred.)

3. General factors

In this section factors that may not be connected to a specific task and could not be included in the SHERPAs are discussed.

3.1. Improvement work

In Lund WCM is used for continuous improvement, always involving the operators in the improvement work. One large part of the WCM work is the Autonomous Maintenance (AM) Pillar. During the visit in Limburg an AM project had just been completed and the evaluation of it could be studied for the Master Thesis. This provided good insight to what type of solutions WCM/AM work can result in and how dependent it is upon engaged individuals coming up with and creating their own solutions. In Limburg the operators that were interested were chosen to participate in the improvement work and hence the same operators often participated in a large proportion of the projects. One of the operators in Limburg explains it as follows:

"I appreciate the possibilities to improve and change how tasks are executed and also the possibility to be versatile and constantly learn new things." (Interviews)

The opinions regarding improvement work in Lund varied both among operators and between the two departments. The mounting department had reached further in the AM scale, see *Theoretical Framework (*D:10.1.2), and many improvements and solutions were mentioned and discussed during the observations and interviews. It was evident that a few operators who enjoyed the improvement work drove it forward. Without those individuals the department would probably not have been as positive towards the projects. One operator expressed that it was important for the teams to work collectively, so that everyone gets a say when a change is coming up (Interviews).

3.2. Shift work

The factories in both Lund and Limburg use shift work to be able to produce enough clichés for printing. The Cliché Making department in Lund has three shifts working on a rotating schedule. Each shift work morning, afternoon or nightshift, all weekdays not including weekends. Cliché Mounting in Lund on the other hand works everyday of the week with morning afternoon and night shift during the week and two 12hour shifts over the weekends. These shifts are divided among four shifts. The Limburg factory uses rotating shifts as well and additionally they have parallel rotation schedules for both departments, meaning that the same two shift groups always work along with each other. In both Lund and Limburg the shifts rotate clockwise, i.e. morning-afternoon-night, which facilitates adapting to new working hours.

Experienced issues with working shifts, especially night shifts, varied among the operators. Some said it put a strain on the body after a few years while others meant that either you get used to it after some time or you never will. One operator in Limburg, that had worked within the same shift for over ten years, expressed that he still found the night shifts to be *"horrible and hard to get used to"* (Interviews).

In production the goal is to continuously produce the same end-result with the same quality. With shift work it sometimes becomes an issue since all shifts do not use the same techniques and thus produce differing results. By introducing standard instructions through WCM work many of those issues are dealt with both in Lund and Limburg. However, despite the existence of detailed education material and manuals it was often experienced as easier to simply ask a colleague. This was expressed in interviews in both Lund and Limburg. This is important to keep in mind when implementing new standards since issues may be transferred to new employees despite new and improved instructions.

In Lund the 12 hour shift needs to produce more than 8h shifts since the target is based on productivity per time unit. The higher target creates stress among the operators and it might be explained with that it is hard for them to remain focused for 12 hours in a row, especially during inconvenient working hours.

For both factories the targets for nightshifts were equal to other shifts which can be questioned. One operator expressed how the capability to remain focused was reduced during a nightshift (Interviews). On one of the sites, both operators and management expressed that the environment was more relaxed during night shifts. This was also experienced firsthand during observations of a nightshift.

3.3. Productivity demands

As a productivity target Lund factory uses a so called EE-target of 80% which represents a goal of 80% of the possible production to be achieved by each shift. That number is created from an estimate of how long it takes to mount an order, not taken into account if it is for example a co-print or the number of lanes used for the format. The target is placed on a table on a large whiteboard in the mounting area and each shift adds what they achieved during their shift. If the target has not been reached, reasons for this are noted and discussed during the following shift meeting. Breaks are not included in the time frame for the target and some employees have expressed that this is a stress factor and that they have to plan well when to go on breaks.

In the Lund factory the operators most often reached the goal but they still expressed that it was stressful to need to reach the goal each time. Consequently they felt that this sometimes affected the quality of their mounting. Additionally a reached target before the end of the shift often led to decreased productivity during the time left.

It was also expressed that the management had shifted back and forth between putting focus on meeting targets and on minimising shortstops in printing or customer complaints. During interviews operators expressed how some teams always reached the targets but their number of returned sleeves was relatively high as well. One comment in mounting Lund was: "*when the production target is too much in focus mounting personnel tend to mount without doing their final sorting, checking that the clichés are in the correct order*." (Interviews)

In the Cliché Making department in Limburg each shift needed to finalise clichés for a certain amount of orders each shift. Each order was printed out and placed in a drawer when completed. At the end of each shift the number of orders was counted and the number entered in a file on the computer which was regularly checked by the production manager. To be said is that Germany has restrictions against documenting productivity of a single employee or a single shift and therefore the total for all shifts for 24hours was the most detailed information available for the management.

To conclude, both factories stated clear goals for the operators that were often, but not always, achieved, in a way showing that they are reasonable targets to achieve. The quality of what is sent to printing is however affected by the, according to some, highly stressed production goals (Interviews).

4. Result analysis of Lund and Limburg

In the previous chapter the most critical issues with the processes in Lund and Limburg have been outlined, and remedial strategies have been suggested. Now follows a comparison of the two factories. Since the Lund factory uses a digital cliché making process and Limburg an analogue there is a large difference on how the entire processes look and thus the final issue quantification cannot be seen as the complete truth. The subtasks under each machine task will differ and hence so will the issue distribution. However comparing the tasks offers insight to where critical issues have the highest impact.

4.1. Comparison of the Lund and Limburg processes

In figure F.4 manual tasks are represented by circles and more automated, or machine based, ones by squares. The figure clearly shows how the number of manual tasks decreases with the implementation of a digital cliché making process and where the majority of manual activities take place in the process. It also shows that a central manual activity, in common for both Lund and Limburg, is the sorting of clichés that takes place before they are delivered to Cliché Mounting.

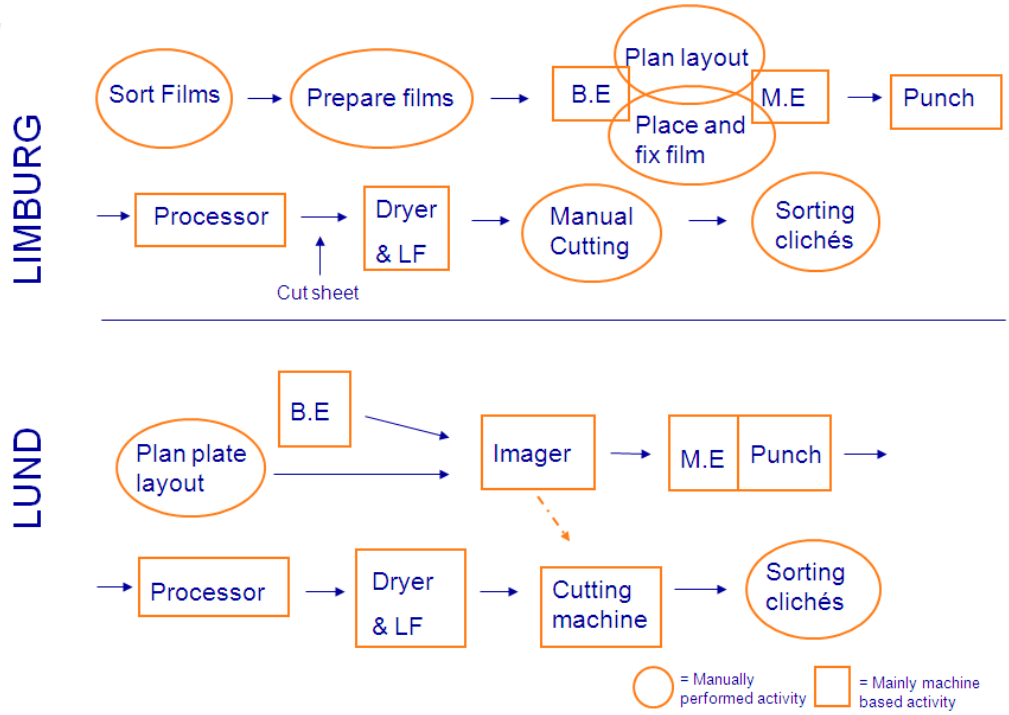


Figure F.4 Comparison of Cliché Making in Lund and Limburg

The manual tasks that complicate the Limburg process is the placement and handling of films and also manually cutting out each cliché. However the manual cutting gave the possibility to cut each plate in half before placing it in the dryer. This is not possible in Lund since the automatic cutting table needs the complete plate for cutting each cliché correctly in relation to the rest of the sheet. This limitation is a great example of how automation does not only eliminate issues but sometimes also complicates a process and creates the need for alternative solutions.

After the visit to the Limburg factory a brief comparison was presented to the Limburg production management. The results are summarised in table F.1 and some further discussions follows.

Table F.1 Comparison of the Pre-press departments in Lund and Limburg, example of advantages and disadvantages

Lund	Limburg
Organisational:	**Organisational:**
+ Strong focus on ergonomic issues	+ Aim to integrate the two departments
+ Open discussion on ergonomic issues	+ Communication throughout organisation
+ Involvement of operators in improvement	+ Involvement of operators in improvement

work (WCM) + Gender diversity **Process solutions** + Puncher incorporated in exposure unit + Automatic cutting + Height adjustable floor in mounting machine + Automatic pressure roller + Sleeve trolleys, horizontal with fewer sleeves + Sleeve trolley placed next to mounting machine + Automatic processor out feed facilitates task	work (WCM) + Clear goal that operators should have understanding of process **Process solutions** + Possibility to cut plate in half + Good layout, all machines in one line + Aim for all operators to know all tasks, possibility to rotate between departments + Reduced sorting due to new standard (post-its) + Home-made solution to processor done - decreases scratch problems and ergonomic back issues
- Separated departments - Unfavourable factory layout	- Manual cutting, time-consuming and standing - No gender diversity

Lund factory proved to have a large focus on ergonomics combined with a very open climate to discuss and improve those types of issues. Limburg on the other hand had less ergonomic focus which was evident in the choice of trolleys and the absence of ergonomic aids and also the small amount of complaints coming from the operators. This could be due to both a more open working culture and higher ergonomic awareness in Lund. However, both factories are much focused on WCM development work and engaging the operators in that work.

Limburg put a strong focus on creating a common working place, including both departments. They expressed an aim to increase communication and the possibility to educate the operators to work in both departments since this would reduce the operator dependency. Lund showed little attempts for this and the two departments seem distant. To make rotation between the two departments possible, the interviewees, in Limburg, pointed out the importance of practicing newly acquired skills before they were lost again.

Another clear difference was the distance between management, development and production. Despite the fact that much development takes place in Lund the cooperation between D&E and production is very limited. Development for production goes through the channel of WCM improvement work while D&E reaches the production quite late in the development process. The factory in Limburg consists of a much smaller organisation and despite more hierarchical relationships the distance between executive management and a production operator is smaller. The visit in Limburg gave a view of a management in close relationship to the employees.

In Lund, the gender diversity is well distributed and especially in Cliché Making women make up a significant part of the workforce, whereas in Limburg no women were employed. Gender diversity obviously affects the physical demands of a workplace but it also adds to the dynamics of a group.

4.2. Analyses of critical issues in Lund and Limburg

When looking more closely at the type of issues rated as critical in both Lund and Limburg only the Cliché Making departments were compared due to the lack of information collection in the Cliché Mounting department during the visit to the Limburg factory. Figure F.4 shows that the total number of critical tasks was very similar for the two factories whereas the number of issues connected to physical ergonomics represented more than half of the issues in Lund and only a third of the issues in Limburg. The fact that Limburg rolls the plate between machines, the close placement of the machines and the possibility to cut the plate in half can serve as a brief explanation to these results. See a thorough process description in Appendix 1.

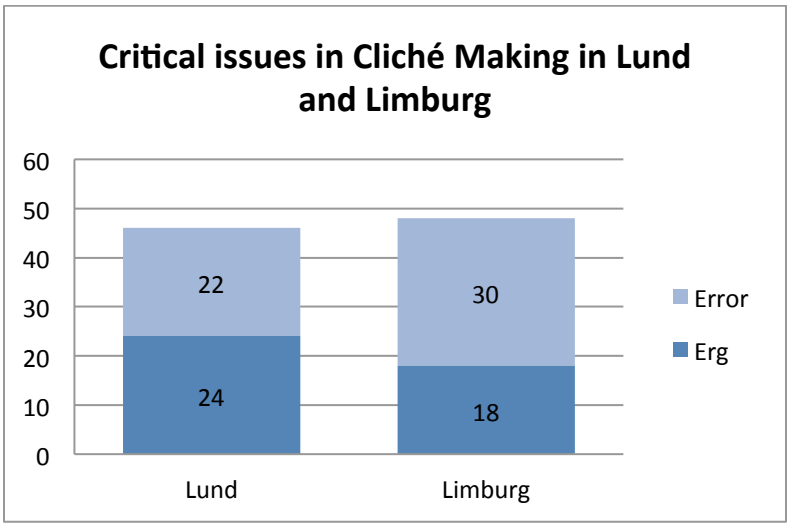


Figure F.4 Critical issues in Cliché Making in Lund and Limburg

Looking closer at how the critical issues are distributed among the different tasks in the two processes both similarities and differences are apparent. Figure F.5 shows the distribution within Cliché Making in Lund and figure F.6 in Limburg.

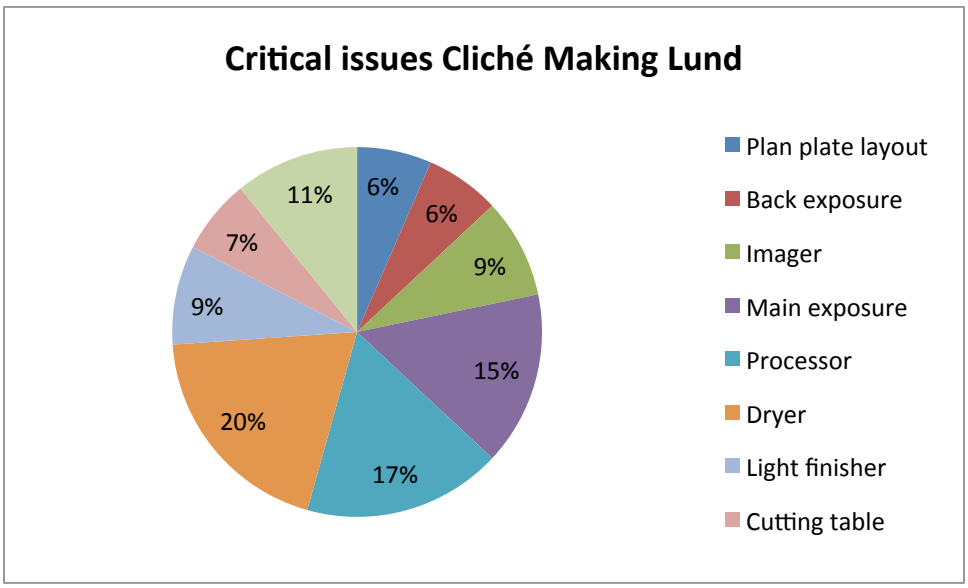


Figure F.5 Distribution of critical issues in Cliché Making, Lund

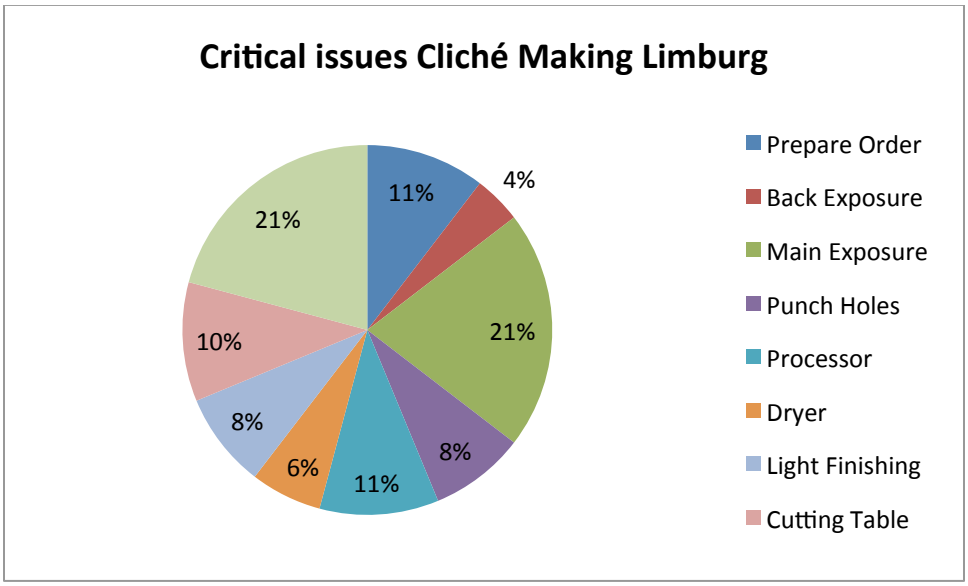


Figure F.611 Distribution of critical issues in Cliché Making, Limburg

What was mentioned above about fewer physical issues regarding plate handling in Limburg can be seen by the smaller proportion of issues related to Processor, Dryer, and Light Finisher in Limburg compared to Lund. In Limburg the largest proportions are instead related to the Main Exposure and the Sorting task. Many of the issues related to the Main Exposure in Limburg result from the placing of the analogue films on the plate. These issues are both ergonomically and human error related, because the operators stand bent while reaching across the exposure surface to place the films as efficiently and correctly as possible. These issues could be minimised using a digital process instead. The large sorting proportion is partly explained by the fact that sorting in Limburg is done once, in Cliché Making, whereas in Lund it is done twice, once in Cliché Making and once in Cliché Mounting. Cutting lane and date marks were

identified as critical tasks in both in Lund and Limburg but in Limburg this task is done in Cliché Making and in Lund in Cliché Mounting, which is also reflected in the comparison above.

Both sorting and placing of the films in the main exposure are tasks requiring high focus and during the interviews in Limburg the operators expressed that these tasks were more demanding than many of the other tasks. When a high focus is required there is a greater possibility for human errors, which is confirmed when looking at the total amount of critical human error possibilities in the Limburg process, see figure F.4.

As mentioned before, since the subtasks under each machine task differ, so will the issue distribution among the tasks. This makes it very difficult to make a fair comparison of the two processes. For that reason the human error identification should be valued more highly than the quantification of the SHERPAs when attempting to identify the strengths and weaknesses of the different processes.

G Results – Predictive analysis

In this chapter the issues with Easy ITS are outlined. For each step a summary of issues are presented with a main focus on reoccurring and/or issues rated as critical in the predictive SHERPA. Mentioned difficulties are based on issues identified in the study of the existing Pre-press line, the predictive human error analysis, and executed interviews and observations. Additionally, detected remedial strategies that can improve the task execution are summarized for each process step and finally a comparison of existing Pre-press and Easy ITS.

For a complete process description, with in-depth descriptions of tasks, issues and remedial strategies for each task, see appendix 2 (Process description: Easy ITS). The task analyses and the detailed SHERPAs are found in appendix 5 and 7.

1. The Easy ITS line

The new Easy ITS process will deliver the same end-product as existing Pre-press does today, and the digital plate making process will be used to do this. However there is another processing order than in the existing line and the manufacturing steps done in the existing line are now implemented and combined in more automated machine solutions.

Before an order arrives to the production it travels via a number of instances and is planned through the cooperation of several departments within Tetra Pak. These processes around Cliché Making and Cliché Mounting will not be affected by the implementation of the Easy ITS line.

The production planning is based on orders arriving to Customer Sales Representatives, who gather all orders worldwide and distribute and assign them to the different Tetra Pak factories. The orders are then sent to production through the computer system P2. In the Customer Folder Archive, production orders and reference printouts are archived and prepared. The files needed for imaging and reference printouts are provided by the Digital Files office. These activities are described in more detail in appendix 3 (*In depth study: Sorting*).

When an order has been prepared by the above instances it is time for it to be manufactured, which is done in the Pre-press department. As opposed to before, Cliché Making and Cliché Mounting are no longer separate departments since the process is combined in the new Easy ITS line.

2. Process description

Through the predictive human error identification analyses, error possibilities, error consequences, recovery possibilities and remedial strategies are identified for all process steps. Additionally the probability and criticality of each issue is considered. In this section the issues rated as critical and/or are reoccurring are outlined together with suggested remedial strategies.

The interested reader is recommended to also read appendix 2 *(Process description: Easy ITS),* where each process step is thoroughly described in the form of task description, summary of common and/or critical issues and remedial strategies for minimising the consequences of those issues. Additionally each section includes a visual representation of the hierarchical task analysis produced as a basis for the evaluation.

2.1. Easy ITS

The number of process steps is decreased due to the new Imager combi that includes three of the previous steps in Cliché Making and the new processor that incorporates the functionality of the previous processor, dryer and light finisher. Figure G.1 functions as an overview to illustrate how the tasks performed by the operators are combined. In appendix 2 (*Process description: Easy ITS*), each task step is illustrated separately. The numbering used in the hierarchical task analysis is also used in the process descriptions.

1. Plan plate layout
2. Imager combi (back exposing, imaging, main exposing)
3. Cutting machine
4. Sorting
5. Tape mounting
6. Plate mounting
7. Processor (processing, drying, light finishing)
8. Finalise order

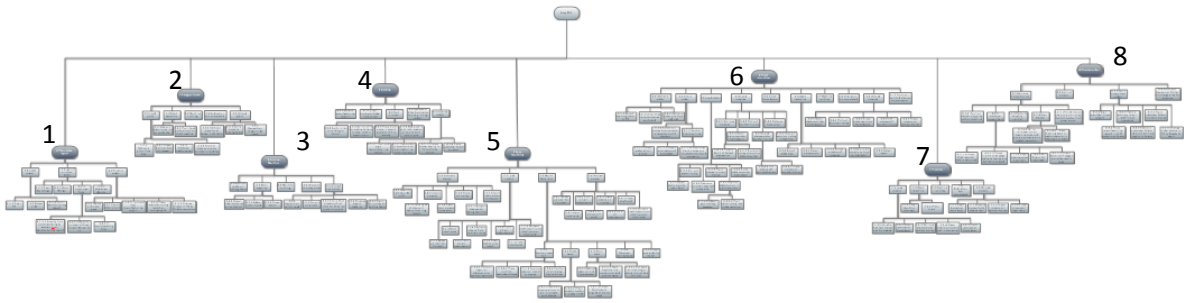


Figure G.1 Hierarchical task analysis of Easy ITS

1. Plan plate layout

In the first step of the Easy ITS process, the processing of the orders is planned in a similar way to how it is done in Pre-press Lund.

Identified issues

- Setting the incorrect status in the computer program P2 causes implications (risk that order is redone).
- Pop-ups, that cause action delays and leads to irritation, often occur in P2.
- Prioritised orders are missed when identifying orders in P2 due to not reloaded order list or the human factor.

- It takes time to learn how to best combine the décors on a plate but once this has been learned the task is no longer critical.

Remedial strategies

- Only relevant statuses should be available for selection in P2.
- Clear colour coding would improve the P2 interface and make information retrieval and selections easier.
- The use of pop-ups should be minimised.
- Automatic continuous reloading would improve order selection.
- To minimise steps, automatic programming to download and rip correct files should be investigated.
- The plate layouts should be planned with consideration to sorting. The same colour should be combined on a plate rather than décor design to make the sorting of co-prints more efficient.

2. Imager combi

In the imager the information from the organising of the décor is used to treat the black layer of the plate with laser beams. Directly after a section is imaged with the laser it is also main exposed and finally back exposed.

Identified issues

- Loading causes discomfort due to the height of the imager comb. However, it is a smaller issue with the new process since there is automatic loading and the plate only needs to be placed on top of the machine.
- The plates are stiff and easily breakable before they are placed in the Imager combi.

Remedial strategies

- A movable footstool should be provided to improve the working height (is done in Lund today).
- A pallet placed on a lift to keep new plates on a suitable height at all times would facilitate loading.
- A sliding function for loading and unloading would facilitate plate handling.
- Placement of the machines in a single line would also reduce plate handling.
- The output plate is less fragile in Easy ITS since it has been main exposed in the Imager combi as well.
- Repositioning of the laser is no longer an operator task.

3. Cutting machine

The cutting machine automatically cuts along the décor edges imaged on the plate, according to the imaging file, and delivers the finished clichés. The cutting machine used in Easy ITS today is similar to the one used in Pre-press.

Identified issues

- Leaning over the table when placing the plate is an inappropriate posture that may cause discomfort.
- The task of adjusting the cutter head before cutting each plate is time consuming.

- The task involves standing for long periods of time, which can lead to discomfort.
- High demand on good visibility.

Remedial strategies

- Rubber carpets should be placed in front of the cutting machines to ease discomfort in back from standing
- The task distribution should be planned to create a mixture of standing, sitting and moving (e.g. rotations within the shift).
- Automatic repositioning of the cutter head could be implemented in the Easy ITS cutting machine.
- Investigate pen function to mark clichés and if additional cutting machine is needed to meet efficiency demands. Additionally it is important that the pen function is reliable, as there have been issues in the past.
- If the plate is placed on a bright surface the black layer on the plate improves the visibility of the cross marks.
- The stress and the required level of focus in this task should be considered when distributing tasks.
- It should be investigated if it is necessary to clean the backside of the cut plates.
- Lighting needs to be sufficient.

4. Sorting

One major difference with the new process is that sorting of the clichés is only done once. The operator organises the clichés in order and places them together with the manufacturing report in a pile on a shelf.

Identified issues

- For this task there is time pressure and a high need to remain focused.
- Additional force and high elbows are needed to separate sticky clichés.
- The task involves standing for long periods of time, which can lead to discomfort.
- High demand on good visibility.
- Setting the incorrect status in P2 causes implications and there is a risk that the order is lost.

Remedial strategies

- All information required for sorting should be provided on the manufacturing report.
- Plans for sorting should be done already when planning plate layout. The same colour should be combined on a plate rather than décor design to make the sorting of co-prints more efficient.
- A light table should be provided to improve visibility when sorting clichés.
- The black layer on the plate improves visibility of the plate numbers if placed on a bright surface.
- Job rotation within each shift should be encouraged.
- Area for sorting should have adjustable height to enable both standing and sitting.
- Rubber carpets should be provided to ease discomfort in back.
- Only relevant statuses should be available for selection in P2.

- Clear colour coding would improve the P2 interface and make information retrieval and selections easier.

5. Tape mounting

The Easy ITS process will use a semi automatic tape machine to mount tape onto the sleeves before they can be placed in the mounting machine.

Identified issues

- It is important to communicate what sleeves should be taped next.
- It is important that required sleeve types are available.
- There is a range of possible ergonomic risks when retrieving sleeve from storage.
- There are large ergonomic risks due to twisting grips and lifts when using the vertical trolley.
- The lever used to lift the sleeve shaft is too heavy.
- There is a high risk of misaligning the tape, meaning it either has to be redone or is sent away and causes later implications. This task is time-consuming and includes ergonomic risks.
- Task involves unfavourable postures due to leaning and lifting arms above tape roll when positioning the tape.

Remedial strategies

- It is necessary to find solution about how to communicate what orders to be taped and when it needs to be taped to be ready for mounting. (Few sleeves are available and storing time for clichés is possibly limited.)
- The shelf used today should not be used in Easy ITS. A solution could instead be a rotating shelf system for sleeve storage that delivers all sleeves on an appropriate height.
- Placing sleeves directly on trolley used for mounting should be considered.
- Lifting of shaft should be done automatically, using e.g. electronics/motor.
- Taping machine should be redesigned, e.g. box should be decreased to minimise leaning and tape roll should if possible be lowered.
- Consider using a Microflex machine to mount tape, assuming enough space is available.
- Carrier paths crossing walking paths should be avoided when planning the factory layout.

6. Plate mounting

Plate mounting involves loading the machine with correct sleeves and corresponding pile of clichés. The machine then mounts clichés onto each of the taped sleeves.

Identified issues

- If communication The required sleeves are not taped.
- A sorting check might be omitted or previously done errors remain unnoticed.
- There is a risk that an incorrect pile is selected to be placed in the plate trolley.
- The positioning toggles on the plate trolley are difficult to adjust.
- The task of loading and unloading sleeves from vertical to horizontal trolleys involves ergonomic risks.
- Keeping track of and reporting deviations in the machine settings might become an issue.

- There is a risk that it is only possible to store the clichés for a limited time period.

Remedial strategies

- It is necessary to find solution about how to communicate what orders to be taped and when it needs to be taped to be ready for mounting. (Few sleeves are available and storing time for clichés is possibly limited.)
- Information material and education about sorting, the mounting procedure and machine settings are important.
- Filling all empty lanes on the sleeve with blank plates could be helpful.
- Extended use of the mounting trolley should be implemented.

7. Processor

The new processor incorporates three main functions; it removes the unhardened polymers, and then dries and light finishes the sleeves and clichés.

Identified issues

- There is an unclear indication of when a new sleeve can be loaded for maximum efficiency.
- There are ergonomic risks related to loading and unloading the sleeves to and from the vertical trolley.
- The front door handle is placed high up and force is required to open.
- Tall operators need to lean back and reach when loading the machine, which can lead to discomfort.
- When cleaning the processor the operators are exposed to the solvent chemical.

Remedial strategies

- An indication to start loading should be present as soon as it is possible to load the processor with a new sleeve.
- There should be automatic closing and opening of the doors, preferably with a button or pedal.
- It should be investigated if it is possible to open the doors more to allow tall operators to get closer to the sleeve rest when loading.
- The machine line layout should be optimised to improve visualisation of indication that sleeve is finished or that a new one can be loaded.
- The vertical trolley should be avoided, especially since the sleeve is placed horizontally on the rest in the processor.

This new machine eliminates the use of dryer and light finisher and thereby reduces plate handling to a large extent. Nor is there any need to handle slippery solvent covered plates.

8. Finalise order

In this step some or all sleeves in an order is checked in the quality control unit before approved to be sent to printing. Also, the paper work is filled out and placed in the correct place for future use.

Identified issues

- When moving the sleeves to the quality control machine from the vertical trolley, and vice versa, there are large ergonomic risks due to twisting grips and lifts.
- Risk of colliding with automatic carriers when transporting sleeves to Printing.
- Setting incorrect status causes implications (risk that order lost or redone).

Remedial strategies

- Carrier paths crossing walking paths should be avoided when planning the factory layout.
- Avoid using vertical trolley, especially for heavier sleeves.
- Only relevant statuses should be available for selection in P2.
- Clear colour coding would improve the P2 interface and make information retrieval and selections easier.
- Paper forms used should be looked through and unnecessary information should be removed.
- The possibility to connect paper forms to P2 should be investigated, e.g. that all necessary information have to be entered before the order is sent to Printing. (Note: Information on paper is sometimes preferred.)

3. Result analysis of Easy ITS

A range of issues concerning the Easy ITS work process have been identified through the predictive SHERPA. When comparing the criticality ranking for the different machines within the Easy ITS line it is clear that the distribution is very uneven. The largest group of issues are related to tape mounting, both because of sleeve handling and machine design, see figure G.2.

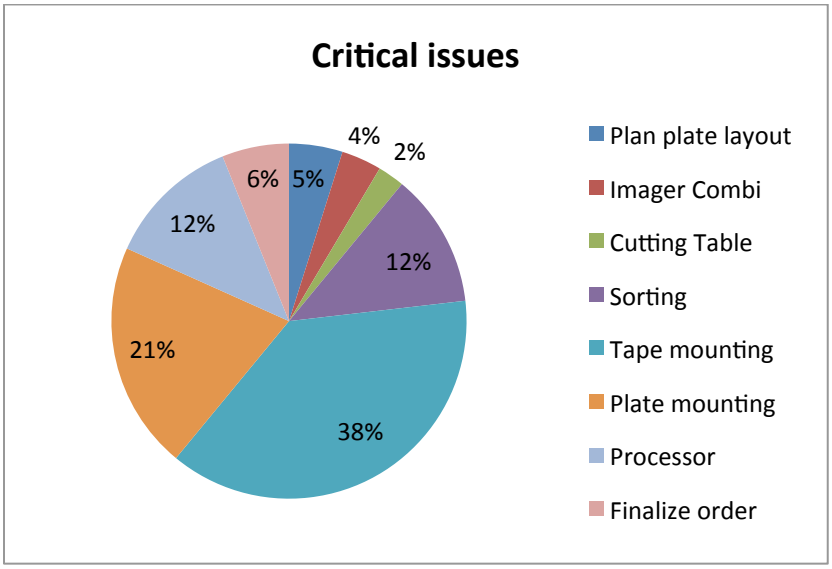


Figure G.2 Critical issues in Easy ITS before suggested improvements

As the tape machine is still under development it is interesting to see that improving its design and minimise related sleeve handling would highly improve the process in terms of criticality. In Lund Pre-press 4 critical issues were related to the taping, in Easy ITS this number is as high as 31. Since taping is

done very differently in existing Pre-press compared to Easy ITS this is not a fair comparison to make. In Easy ITS more activities are involved in this task step and a separate machine is used. However, by studying figure G.3 below it also becomes clear that it should be possible to improve the taping process for Easy ITS just as Lund Pre-press has developed technology to make the taping task better for the operators there.

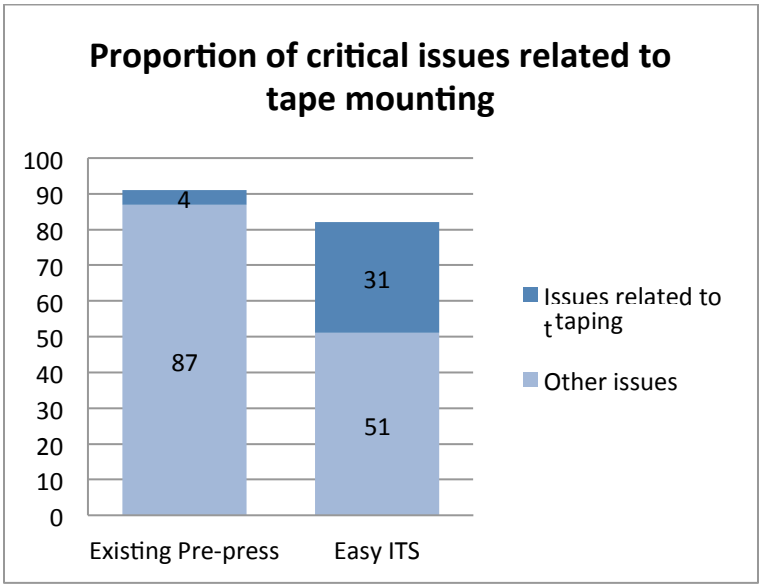


Figure G.3 Proportion of critical issues related to tape mounting in Existing Pre-press and Easy ITS

If looking at Easy ITS with and without the tape mounting it becomes clear that tape mounting is the task most influencing the total error criticality and therefore putting effort in a better taping solution would be beneficial, see figure G.4.

Plate mounting creates the second largest number of critical issues, see figure G.4. This task includes many small steps for the operator which increases the risk of errors in general. Another reason for the high criticality is the limited possibility for recovery, once the machine is started there is little chance to undo an error of for example sorting or program settings.

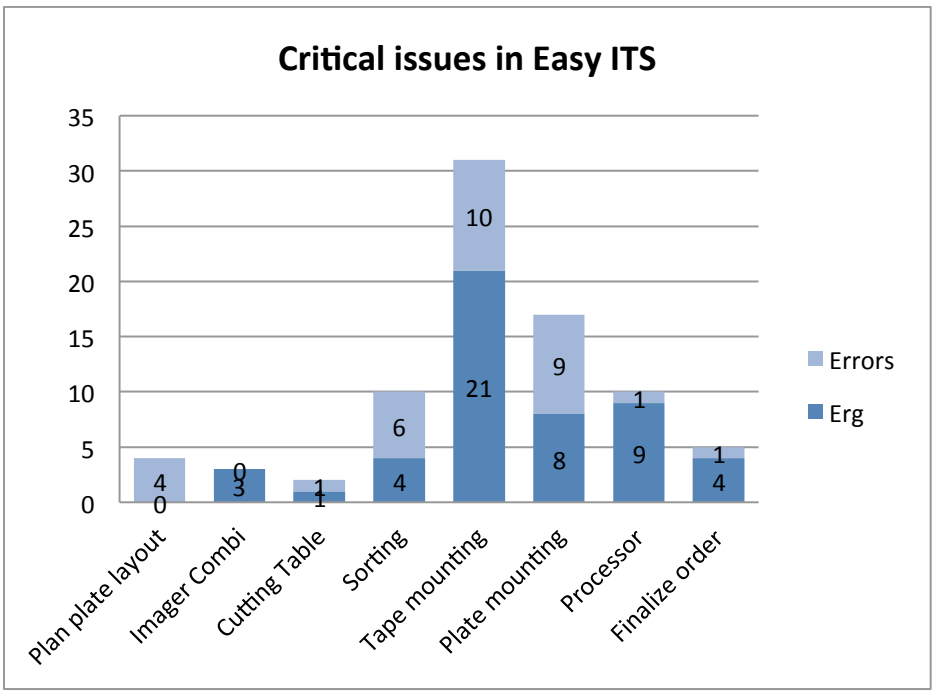


Figure G.412 Critical issues divided into human error and ergonomics in the Easy ITS process

The issues from the SHERPAs can be related to either ergonomics (Erg) or human error (Errors). The distribution can also be seen in figure G.4 above. The largest proportion of ergonomic issues is related to sleeve handling and the majority of these issues are related to moving the sleeves from a trolley to a machine (or vice versa), especially when vertical trolleys are used for heavy sleeves. One of the suggested remedial strategies, that also has been discussed with members of the Easy ITS team, is to extend the use of the trolley used in the mounting machine. After taping, the sleeves can be directly placed on this trolley, and after mounting the sleeves can be directly transported to the processor. However, there are ergonomic issues related to this trolley too, for example that the lowest sleeve placement is too low. Nonetheless extending its use would remove all ergonomic issues related to plate mounting since the operators will not have to change trolley before mounting. Since it is horizontal and both the tape machine and the processor are loaded from this angle two twisting actions can also be avoided. This impact together with the impacts of other suggested solutions will be described and illustrated in the figure G.7, later in this chapter.

The processor is an example of fixed automation and multiple previous tasks are now combined in one machine. In the processor the sleeve (with clichés) is first processed and then automatically moved into a dryer box for drying and finally a light finishing box. In the Pre-press process today the plates are very fragile after processing and before they have dried, and the dryer and light finisher designs resulted in a wide range of ergonomic issues. By combining these steps in the same machine, the critical tasks between these machine steps can be eliminated. In figure G.5 below the amount of critical issues related to the processor in Easy ITS is compared to corresponding errors in the processor, dryer and light finisher in existing Pre-press in Lund, showing how this improvement changes the data.

It should also be said that the Easy ITS processor is loaded with sleeves whereas in existing Pre-press, the processor is loaded with plates. This means that some issues may have been added due to sleeve handling explaining why the Easy ITS Processor has more critical issues than the old processor.

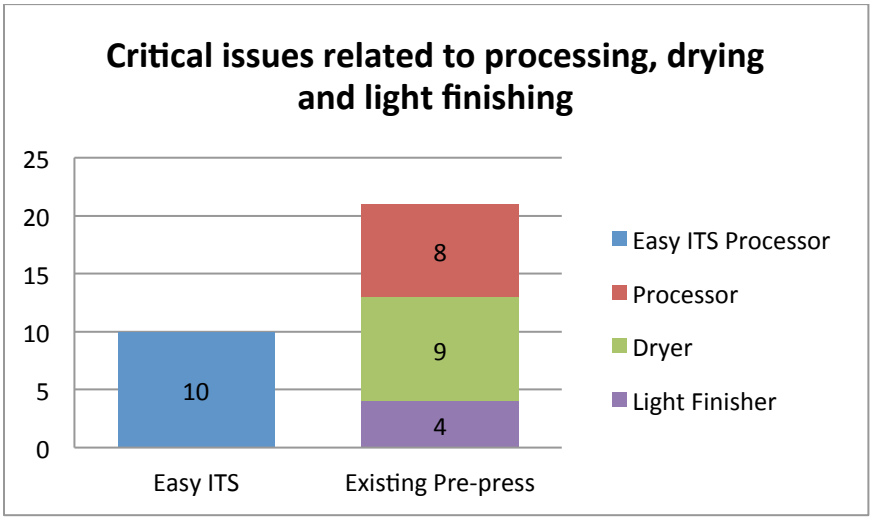


Figure G.5 Critical issues related to the Easy ITS processor compared to processing, drying and light finishing in Lund Pre-press

To investigate how the Easy ITS stand in relation to existing Pre-press the error criticality for the two processes are compared. The result is illustrated in figure G.6 below.

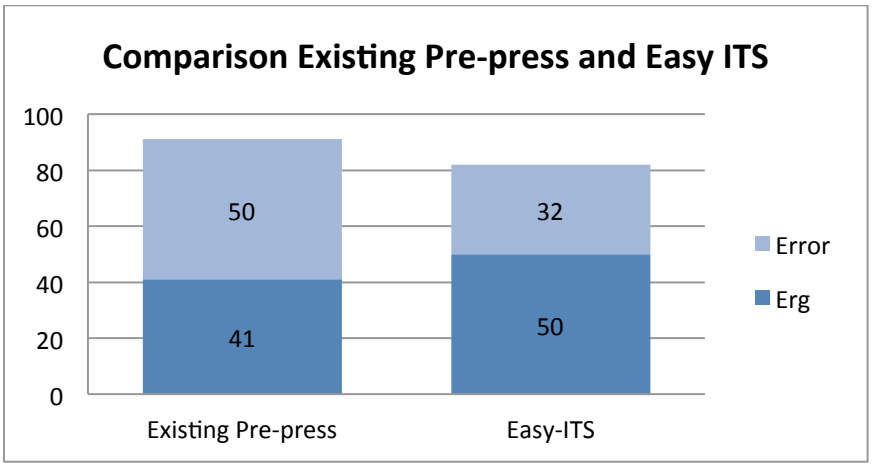


Figure 13 Comparison of critical issues in Pre-press and Easy ITS, share of ergonomic related issues

When comparing the issues resulting from existing Pre-press SHERPAs with the Easy ITS SHERPA, before the implementations born from this project, the numbers of critical issues are not that different from each other. However, even if the numbers in total appear similar different parts of the process have changed in different ways. When looking more carefully at the numbers it is interesting to see that it is the ergonomic issues that have shifted the most.

The existing Pre-press process have many more tasks and involve a larger number of machines than Easy ITS. One obvious consequence of this is that the frequency of loading and unloading machines will decrease. Especially ergonomic issues related to plate handling has decreased. Reasons for this are that many functionalities are combined in the same machines in Easy ITS. The Easy ITS processor has already been mentioned as an example but also the Imager combi combines three previous machine functions (back exposure, imager and main exposure). All of these tasks are separate in the Cliché Making department today and involve a high degree of plate handling.

Despite the dramatic decrease of critical issues related to plate handling the amount of ergonomic issues in total in Easy ITS has still increased, this is a result of the increased sleeve handling throughout the process. In appendix 4 (*In depth study: Manual Handling*), the fact that sleeve handling has increased while plate handling decreased is discussed further. The sleeve handling is highly influenced by the choice of trolleys and also the final choice of tape machine.

By studying the process it has been possible to identify remedial strategies that if implemented will highly improve, and lower the total number of critical issues, for Easy ITS. In some cases a task would be considered as critical also after the implementation of ergonomic aids and more appropriate equipment. However, the negative effects can be considerably decreased and therefore the improvements are still of high importance.

The proposed remedial strategies will be of varying difficulty to implement. Some are costly and requires machine design changes while others need time to make a difference. Since the machines in the Easy ITS project are still under development there are still possibilities for machine design improvements.

The remedial strategies, considered to be easiest to implement in Easy ITS, are:

- Extended use of mounting trolley
- Avoid vertical trolleys for heavy sleeves
- Height adjustable light table for sorting
- Rubber carpets when sorting and cutting, and increased job rotation
- Footstool for imager combi and move handles
- Processor loading improvement

Other implementations would be more difficult to implement, but would also make a big difference for the operators and improve some of the most critical issues. These changes should be considered when planning the implementation in new factories and are the following:

- Rotating shelf system for sleeve storage
- Consider updating tape machine
- Machine and layout design changes, e.g. related to loading (and door heights) in the processor, mounting machine and Imager combi
- Appropriate factory layout planning (avoiding carrier paths crossing walking paths)

The above suggested remedial strategies are discussed in depth in appendix 2 (*Process description: Easy ITS*).

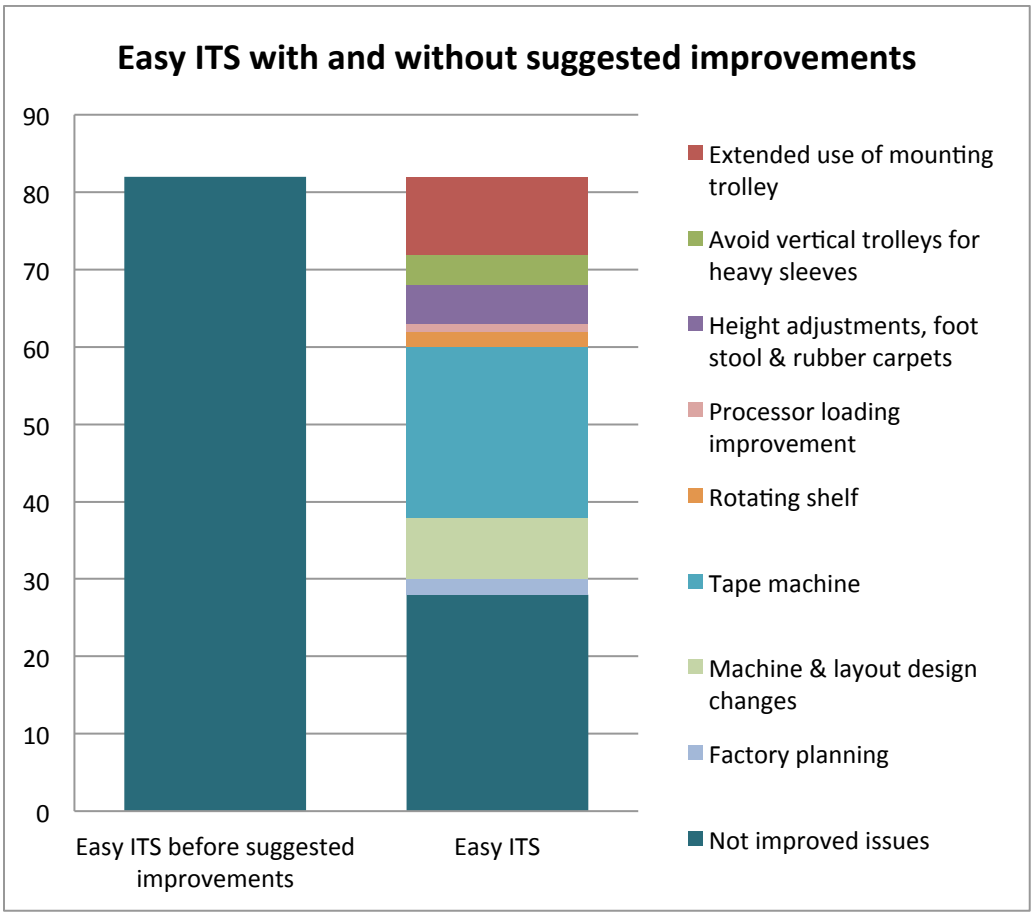


Figure G.7 Easy ITS with and without suggested improvements

As can be seen in figure G.7 above, the criticality of a majority of the identified issues in the Easy ITS process can be reduced. This does not mean that all of these issues can be removed or prevented from occurring. However the negative outcome can be prevented or at least its criticality lowered. For example, lifting the sleeves would still remain an issue even after introducing better designed trolleys, but it is important to take all possible measures to improve what can be improved for the operators.

When relating cost for these types of improvements to its impact on the total process, development of an alternative tape mounting machine is justified by its large impact on the process as a whole. Furthermore, less complicated improvements such as the footstool or rubber carpets have a smaller impact but at the same time, the cost for implementing them is low which makes the investment highly recommended. Figure G.8 below shows that 24% of the detected issues have easy solutions (summarised above), 15% require design changes or are related to machine layout in the factory (summarised above), 27% are related to the taping machine and the final 34 % are issues that have not been given detailed solutions in this study. However brief remedial strategies have been suggested in the SHERPAs and in the summaries.

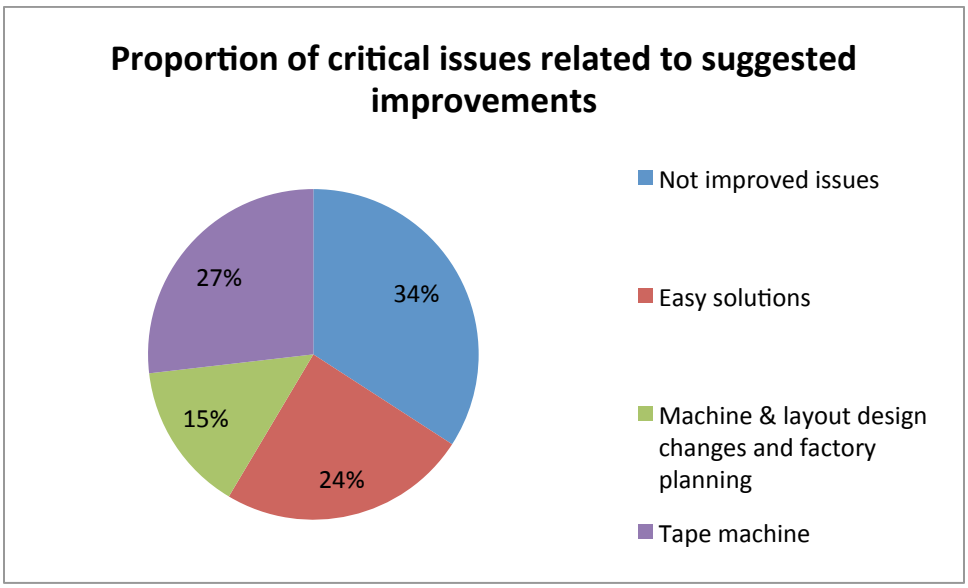


Figure G.8 Distribution of critical issues and suggested improvements

The not improved issues are primarily related to improvements to the computer program P2. Here the interface could be improved to facilitate selecting orders and changing statuses. Other issues are related to checks done after sorting and when loading the mounting machine. Finally a range of issues related to plate and sleeve handling cannot be improved by the choice of trolleys and would require additional measures.

The improvement from existing Pre-press to Easy ITS is a very good example showing that it is not enough to simply automate a process and expect the operators' working environment to improve and operator errors to diminish. An iterative process involving the users is vital also when developing more automated processes.

H Discussion

In the Discussion the results from the study are analysed further along with an evaluation of the chosen study methods. Finally, the use of these methods and suggestions for future work with Human Factors in development processes are discussed.

Since the report, due to the extensive analysis, is long it is suitable to begin this discussion by relating back to the purpose of this Master Thesis:

The purpose is to integrate the operators' working methods and preferences on an early stage in a development project. By using Human Factors methods future difficulties and errors will be identified and solutions delivered. Additionally the use of these types of methods in development work at Tetra Pak will be evaluated and a future approach will be suggested.

The discussion has been divided into three main parts where we start by drawing conclusions from the study. Following is a section discussing the choice of methods and their impact on the end result. Finally, Human Factors in development work at Tetra Pak is discussed including suggestions on how Tetra Pak could work with these types of questions in the future.

1. Conclusions from the study

To make sure the purpose of this Master Thesis have been fulfilled the three main questions, introduced in the introduction chapter, will begin this discussion.

- *What will be the operator difficulties with the Easy ITS production line?*
- *How can these difficulties be mitigated or if not possible decreased?*
- *How can Human Factors methods be used in development work at Tetra Pak?*

The first two questions are answered within *Results - Predictive analysis* (G) and also more in depth in appendix 2 (*Process description: Easy ITS*), appendix 3 (*In depth study: Sorting)* and appendix 4 (*In depth study: Manual Handling)*. Both smaller and larger difficulties were identified and mitigating and preventive actions were suggested to the majority of these issues. It should, however, be said that the *Results – Current situation analysis* (F) about existing Pre-press also provides information and insights that can be helpful in both understanding the conclusions drawn in this Master Thesis and for future development work within Pre-press.

Conducting the study and performing the Master Thesis within the Easy ITS project, has been a hands-on attempt to integrate Human Factors in a development project at Tetra Pak. We have therefore learned a lot about the practically about the techniques we have chosen and how they work within an organisation as Tetra Pak. Consequently, we believe that we now, after soon having finished this Master Thesis and discussed the process, have enough insight to answer Master Thesis question three. This will be done in the end of this discussion chapter where we also will propose how Tetra Pak should continue the work to implement Human Factors.

During the execution of the study it has always been in the back of our heads which process is the *best* and whether the more automated Easy ITS solution improves the work situation for the operators or not. It would have been great to be able to give a straight answer and say that *Yes,* the new Easy ITS process is better than the old one. Unfortunately it is seldom that easy. The result given when comparing the processes in the quantification analysis indicate that there are fewer critical issues in the new process and, if implemented correctly, many issues with the previous process can be avoided. If the Easy ITS line is implemented from scratch this is a great opportunity to plan the factory layout to suit both the operators and the material flow.

The Easy ITS project emphasise the automation of Cliché Mounting as the main strength with the new machine line. However, the results from this study indicate that the Processor and the Imager Combi units make up a very important part of why the Easy ITS will be an improvement for the Pre-press department.

The common occurrence of automation as a solution to production issues and quality flaws is in a way easy to understand. Automation usually means that something will be done equally every time which is usually the correct way. Issues occur when automation is thought to solve issues without creating other complications along its implementation. Automation could be a great solution when all parts of a process are included but when they are not, the tasks not included usually become increasingly critical or important. One example of this is the implementation of an automatic cutting table which of course eliminates the task of needing to manually cut out each cliché. However, it also eliminates the possibility to cut a large plate in smaller pieces to facilitate loading it into the dryers. By studying a process as an entirety similar occurrences this can be avoided or at least foreseen.

2. Method evaluation

When now, after more than 20 weeks, questioning the planning and the execution of the work process, of course there are some things that could have been done differently. In this section we discuss choices made and the impact of those choices on the outcome of the Master Thesis.

2.1. The scope of the Master Thesis

In retrospect it could have been valuable to have a more clearly defined scope already in the start of the project. Making the scope smaller would have enabled more focus on selected issues but the size of the scope still had its advantages in providing a great overview.

We started with focusing primarily on the work process but when talking to the operators it became clear what other aspects of their everyday work that we also wanted to include. For example shift work and the setting of productivity goals appeared to be two aspects highly influencing the operators' motivation and work performance. Another subject that got a greater focus than we initially anticipated was improvement work such as WCM.

2.2. The SHERPA as the base for analysis

The analysis done in this Master Thesis has been extensive and produced great amounts of data. This has not solely been a good thing and one of the known disadvantages of using the SHERPA technique is that it is extremely time-consuming and complex, especially if there are no already made task analyses to start from. The Cliché Making and Cliché Mounting techniques were completely new to us which added additional complexity, time and work.

It would have been possible to create the task analysis on a more general level or select only parts of the process to look at but we chose to produce a quite detailed analysis for the whole line. The major reason for this was to be able to cover all parts included also in the Easy ITS process and subsequently work through and compare the complete Easy ITS line. Furthermore it was useful to separate the tasks further to identify what specific steps of the process that issues were linked to.

The goal has been to keep the level of detail in the task analyses on a constant level. However, tasks including more manual steps become more detailed since the operators here have more tasks. One example of this is the task description of the Easy ITS tape machine that has been described with more tasks than for example the processor. Additionally, tasks with more operator involvement have larger occurrence of human error. The amount of critical issues is thus not directly connected to the level of detail, but to the degree of operator involvement. Consequently, if the level of detail in the task analyses is not consistent, this should not affect the quantitative results.

We chose to use a human error identification approach as the core of our analyses since we wanted to focus on the difficulties the operators might experience with the new process. This way issues at the sharp-end of the process, actively performed, could be systematically identified. Furthermore two of our Master Thesis questions involved identifying and solving issues that the operators may have with the Easy ITS production line.

As the emphasis is put on identifying issues with the process rather than comparing the complexity of the existing Pre-press line and Easy ITS, it would not have been sufficient to solely use human error quantifications (HEQ). A HEQ technique would have produced a number, saying very little about the process and would have lacked the elaboration given when using a HEI. Therefore we feel that a HEI technique was the right approach even though we later chose to quantify this data as well. The quantification was done to illustratively compare the two processes and since the processes have the same end-product and are similar in their execution we feel that it is both possible and appropriate to base this quantification on the previous error identification.

We chose to use the SHERPA technique primarily because it is a HEI technique with a good reputation and, if executed correctly, it facilitates finding all possible issues. Furthermore, by having remedial strategies as a part of the analysis, error reduction is implemented in the procedure. This was helpful since the extent of the analysis made it impossible to go into depth and develop solutions for each error, but now remedial strategies were considered on each step anyway.

One part of the SHERPA was to classify each error using error modes. While working on the analysis this sometimes felt unnecessary and it was hard to see in what way this actually enriched the study.

However, when all critical issues had been defined it was interesting to see which type of errors was linked to each task. After interviews and observations it was detected that the majority of the issues in the production are related to physical ergonomics. Therefore it was useful to also include Ergonomic (Erg) to the error mode classification. By adding *Erg* to the analysis it was possible to detect which steps in a task that had most ergonomic issues, instead of just concluding that the whole task was an issue. Additionally we chose to add latent errors in the SHERPA as well. As discussed in *Methodology* (E), we felt this was useful since both the execution of earlier steps as well as actions not directly connected to the Pre-press production process will affect later parts of the process. It also facilitated understanding the work process as an entirety when investigating what could be improved rather than simply focusing on one small step at once.

From the SHERPA, errors could be identified and it also made us aware of what aspects of the process to question. Much could have been learned by simply asking general questions about steps that had already proven to be an issue. However, for example task 8.5.1 *Reposition the cutter head* or issue *Pop-up causes action delay* related to task 1.1.2 in *Cliché Making* would probably not have been detected when only asking general questions about the process in an unstructured way.

2.3. Data collection and study inputs

Being in the production has given us great insight into the Pre-press process and has also led to an understanding of the operators' everyday work. This has been very valuable and absolutely critical for constructing the predictive analyses for the Easy ITS. Knowing the process was also important when initiating discussions with the operators. In Lund we have been able to keep an open discussion when interviewing and observing the production. We feel that this has allowed unforeseen topics to be discussed as well.

It should be questioned if the Lund and Limburg factories are a sufficiently representative sample to be able to draw valid conclusions. Since the end-product should have the same quality and the work equipment used is similar, the work processes are most likely executed in the same way globally. However, when studying other, more general factors such as improvement work, education and amount of focus on workforce health, these would most likely differ greatly between different sites. The fact that the work climate differed between Lund and Limburg despite their small geographic distance reinforced this belief.

When talking to the operators and managers it became obvious that there is a lot done to implement continuous improvement work, but there are still many things left to consider. We feel that we have got a sound view of the operators' opinions, difficulties and the work process, but if another scope would have been set, it would have been interesting to interview more managers about the relation between the production and development projects within Development & Engineering (D&E).

Finally, it would have been valuable for us to get continuous feedback from Pre-press operators on our suggestions for Easy ITS. This way they could have been developed with a more user-participatory approach. As this was not possible we have instead done validating interviews and had team discussions with members of the Easy ITS team. This has been useful but also made it clear that it is a large

difference between getting feedback from operators performing the working steps on an everyday basis and from developers knowing all machine functions but perhaps lacking experience of using it. Due to this, they have a different framework and prioritisations. This leads us to the third Master Thesis question.

3. Human Factors - A future part of development work at Tetra Pak

We strongly believe that Human Factors should be a part of the everyday development work in a company like Tetra Pak. It can be read about its importance and how it should be done in numerous research articles and books but it was very interesting to see hands-on that there actually is a profound need and that something useful can be taken from a study like this.

Based on our Master Thesis study we consider the SHERPA technique, at the level we did it, to be too cumbersome for other projects of similar or larger size. However, constructing the task analysis was really useful, but could preferably have been done on a less detailed level as well. Selected issues could then be considered on each level, as was done in the SHERPA. One of the strengths is that task analyses can be done already on an early stage in a development project. By doing this, the team members are encouraged to think about the process as a whole instead of only focusing separately on one machine functionality at a time.

Internal machine processing steps are changed and redesigned repeatedly throughout a development process while the gaps, like the ones studied in this Master Thesis, are usually not solved until they arise after implementation. Then corrections and solutions might cost much more in terms of production stops and training. Therefore they should, and could, be studied and identified already during the development process.

Generally it would be beneficial to develop a new product, or machine line, using an iterative process and focus more on the end-user. Since the end-users are the operators that also work within Tetra Pak it should not be hard to include them in development projects as well. If the operators cannot be included in the projects it is even more important that their view is implemented in other ways. To do this, developers need to have a profound knowledge about the working steps and not only the underlying technology. Just as one of the main goals of Tetra Pak's WCM work done today is to increase the operators' knowledge about their machines the same effort should be done to increase the developers' knowledge about the work processes they aim to improve.

We feel that the importance of understanding existing working methods, when working on new developments or improvements, cannot be emphasised enough. Both its limitations and improvements can then be used to truly improve a process.

Automation is a valuable tool to facilitate for the operators but should not be seen as the easy solution. Even automated processes need people to function, and the interaction between humans and machines still needs to be considered. Therefore Human Factors needs to be acknowledged as a competitive mean in successful product development.

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Appendix

Appendix 1 Process description: Pre-press

A presentation of tasks included in existing Pre-press today. Each task is described and issues and remedial strategies are discussed.

Appendix 2 Process description: Easy ITS

A presentation of tasks included in the Easy ITS process. Each task is described and issues and remedial strategies are discussed.

Appendix 3 In depth study: Sorting

A more detailed description of issues connected to sorting tasks followed by suggestions on how to solve similar issues in Easy ITS.

Appendix 4 In depth study: Manual handling

A more detailed description of issues connected to manual handling followed by suggestions on how to solve similar issues in Easy ITS.

Appendix 5 Task analyses

All task analyses made for both existing Pre-press and Easy ITS are here given in written form.

Appendix 6 Interview material

Transcribed material of all interviews and observations done throughout the study. Additionally, checklists and interview questions are given.

Appendix 7 SHERPAs

In this final appendix all SHERPAs done for Pre-press in Lund and Easy ITS are presented.

Appendix 1
Process description: Pre-press

1. Cliché Making

Below follows a presentation of tasks included in what is referred to as Cliché Making. In Cliché making finished clichés are created and the process is divided into the following tasks:

1. Plan plate layout
2. Back exposure
3. Imager
4. Main exposure
5. Solvent processor
6. Dryer
7. Light Finishing
8. Cutting Machine
9. Sort cut plates

1. Plan plate layout

In the first step of the Pre-press process, the production of clichés belonging to an order is planned.

Task

Orders assigned to each factory are organised according to delivery date to printing in the computer a system named P2. Information about the status of the order follows the order in P2 and decides if the order should be chosen for processing in one of the following process steps. New orders with higher prioritisation are added to P2 higher up in the hierarchy and should therefore be processed before later ones, despite the order in which the order has arrived into the program. This means that the hierarchy or list in P2 constantly changes.

The most prioritised order is chosen from P2 and digital files containing the décor belonging to this order are downloaded from the software program *Backstage* and ripped into another software program called *Merge*. In Merge the décors from different orders are positioned and combined on large plates, optimised with regards to both efficient plate use and due time. Finally a manufacturing report is printed and the information about the plate layout is exported to be used in the Imager and the Cutting machine.

In Limburg this step is done manually with analogue films before exposure. Usually films from different orders are combined to fill a plate with as many cliché décors as possible. The films cover the parts of the surface where there will not be a décor, i.e. where reliefs should not be created on the plate. By doing this only the parts that should create a décor are exposed and hence hardened not to be removed in processing. This can be compared to the black layer on the digital plates, where holes are created by the imager where the reliefs are created.

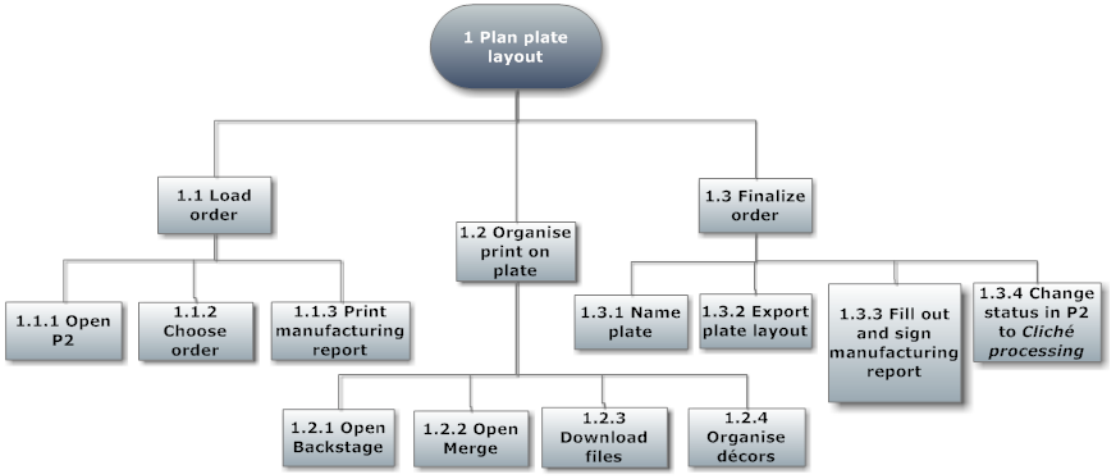


Figure 1.14 Hierarchical task analysis of Plan plate layout in Lund

Issues

The largest issues in this task have been proven to be linked to the computer program P2 that gives the operators information about what orders to process. The program does not update on its own which can lead to that non-prioritised orders are chosen. Furthermore pop-ups occur when someone else is working within the program which causes irritating action delays for the operators. Finally, P2 contains long lists of orders to process where the status of the orders are labelled only with text (e.g. Cliché processing, Cliché in stock, etc). As a consequence the wrong order is sometimes chosen when changing status or the order is given the wrong status. The operators have not experienced issues with organising the plate layout. They feel the digital process has been well translated from the manual of placing analogue films on the plate and that the same knowledge can be used. It takes some time to learn how to best combine décors on a plate but once this has been learned the task is not critical.

Remedial strategies

Clear colour coding would improve the interface of P2 and make order selection easier. The pop-ups when someone else is working within P2 should also be investigated further. The major reason for this is that normally operators are not working with the same order simultaneously and therefore it should not matter if the system would remain unlocked when other statuses are changed. With increased programming, the middle step where the décor files are first downloaded to the software program Backstage and then ripped to be used in Merge could be eliminated and hence save some time.

More solutions as to planning the plate layout in an optimal way are presented in appendix 3 (*In depth study: Sorting*).

2. Back exposure

In the back exposure plates are exposed with light to create a hardened floor. Without a floor there are no hardened polymers keeping the décors together after processing.

Figure 1.15 Illustration of back exposure process

Task

This step is done separately from the rest of the process, a couple of plates are exposed at a time when the operators have time to spare. The plates are collected from a box standing next to the exposure unit and afterwards the plates are piled on a pallet. During this task a plastic cover that protects one side of the plate is kept on. Back exposing in Limburg is mentioned in the task description about the main exposure below.

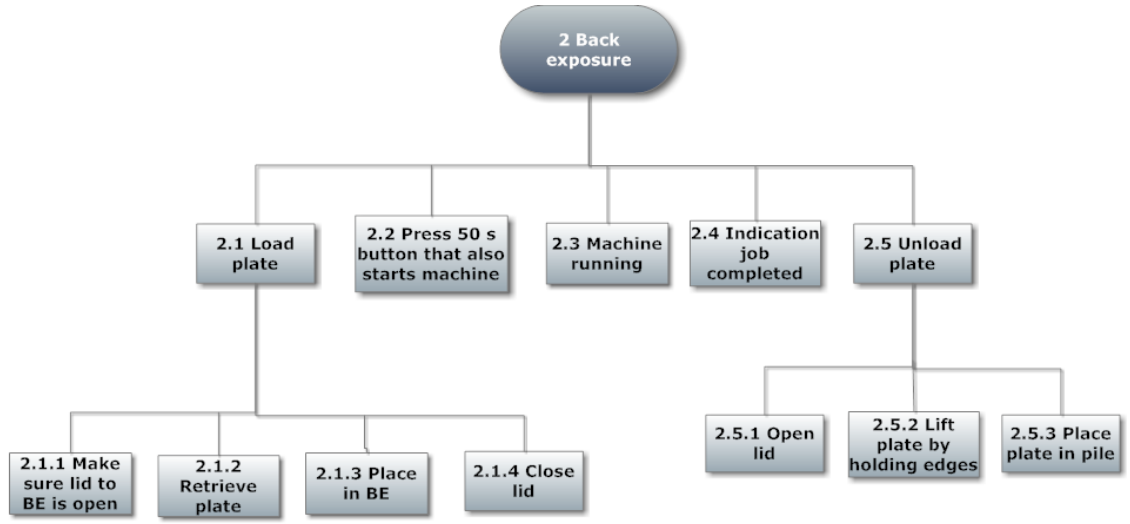


Figure 1.16 Hierarchical task analysis of back exposure in Lund

Issues

The critical issues in the back exposure are related to discomfort resulting from loading and unloading the plates in the machine. Reasons for this are primarily the height of the exposure unit which is an issue due to the large size of the plates and the difficulty in handling them. Another reason for discomfort is closing the lid because when opened the handle is placed high up. The plastic cover protects them from small scratches but also makes them stiff and therefore increases the risk of breaking them.

Remedial strategies

Today the exposure plays a beeping sound when it is ready to be emptied, in Limburg it opened automatically when it was finished. When back exposing, the operators do a batch at a time and usually wait close to the machine while it is exposing, therefore a stronger indication is not required. Automatic opening could still be an idea to implement in Lund, since more than being a useful indication it would also mean that the operators would not have to reach far above shoulder height every time they closed the lid.

Both the ergonomic issues and the risk of breaking the plates can be minimised if the box with the raw plates and the pallet they are placed on afterwards are placed close to the back exposure and on the same height. This pallet could preferably be transported to the Imager on wheels avoiding the need to lift the plates. Then the plates could be slided between the machines. One solution is to have a height adjustable trolley or lift to keep the raw plates on a suitable height at all times. In Limburg the back exposing and main exposing is done in the same machine and therefore the plate handling is decreased.

3. Imager

In the imager, the information from the planning of the plate layout is used to treat the black layer of the plate with laser beams. For the parts that later will be covered by a décor, the black layer is removed (see figure 1.4).

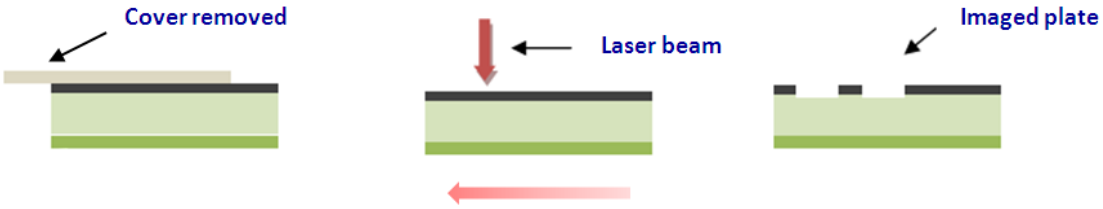
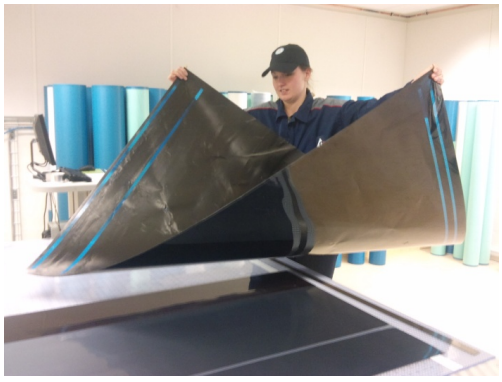


Figure 1.17 Illustration of imager process

Task

In the digital process used in Lund the operator first removes the plastic cover and fastens the plate to a drum. The machine settings, e.g. choosing which plate is being imaged, are entered on both the machine interface and on an adjacent computer. When the machine is finished the display becomes dark to indicate that it is time for unloading. The plate is first rolled out to the surface on top of the imager and then lifted by holding two diagonal corners (see picture 1.1). This grip is possible since the plastic cover has been removed.



Picture 1.2 Operator lifting plate by holding two diagonal corners

The imager is note used in Limburg, instead analogue films are placed on top of the plate surface before exposing, see *Main Exposure* below.

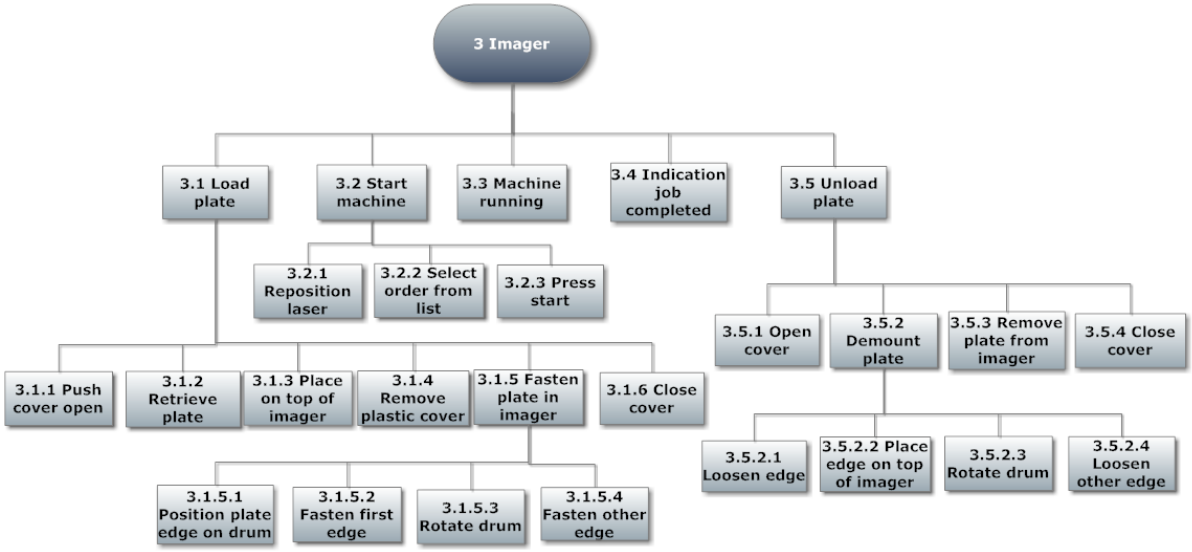


Figure 1.18 Hierarchical task analysis of imager in Lund

Issues

The imager unit is quite high and therefore the task of loading and unloading is uncomfortable for some operators. To facilitate this, a movable footstool is used by the shorter operators, which seems to be appreciated. When the plate has been imaged it is very fragile and the décor is destroyed if touched. Therefore moving the plate to the main exposure, that is the next step, is critical. Attempts to minimise this issue have been investigated by a WCM team that came up with a slide between the imager and the main exposure. Unfortunately this solution was not implemented in a satisfactory way and therefore not used. Another step, not identified as critical but still experienced as irritating by the operators was task 3.2.1 where they had to push a button/code to reposition the laser before imaging. This step had no purpose and could just as easily be programmed to be included in machine functionality.

Remedial strategies

As mentioned above the footstool works well and is appreciated and experienced as helpful by the operators. Since the same operator is handling the Imager for the majority of the shift, placing the footstool is worth the effort. Since the plate is easily damaged after unloading the sliding solution should be further investigated. A larger boarder, with no décor, around the edge of the plate should also be considered, both to avoid fingerprints but also to facilitate gripping. Some operators also expressed that it would be easier to move the plates if the machines were placed in a line, close to each other.

4. Main exposure

In the main exposure, the plate is again treated with light to harden the polymers that later will create the décor on the paper. The light beams will reach the parts of the plate no longer covered by the black layer and hardened reliefs are created (see figure 1.6).

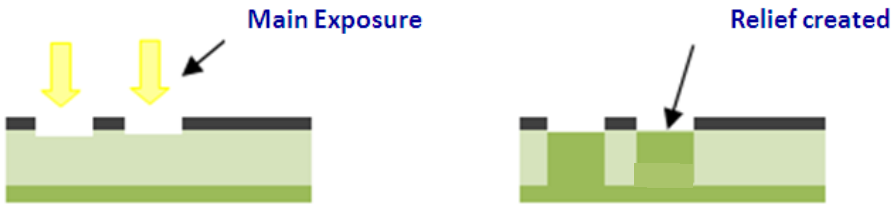


Figure 1.19 Illustration of main exposure process

Task

Main exposing is very similar to back exposing. The same type of machine is used but with a longer exposing time. First, the plate is placed on the exposure surface and holes are punched on the left edge, this is done to be able to load the plate in the next machine, the processor. After punching, the lid is manually closed and the machine is started. When the exposing is done this is indicated by a beeping sound. The operator then opens the lid and lifts the plate by holding the edges diagonally and transporting it to the processor.

In Limburg more steps are done in the main exposure. When the plate has been back exposed it is kept in the exposure, the plate is turned and films are placed. The films are placed based on efficient plate usage and due time of the cliché order. To prevent dust from damaging the clichés, the plates are cleaned with rollers. Afterwards a vacuum cover is placed above and the edges are taped to prevent the décors from moving during exposing. Just as for back exposing the machine beeps and opens when done. When the plate is exposed the operator rolls it together and moves it from the exposure to a separate puncher where they, while the plate is still in a role, place the edge and punch holes using a foot pedal.

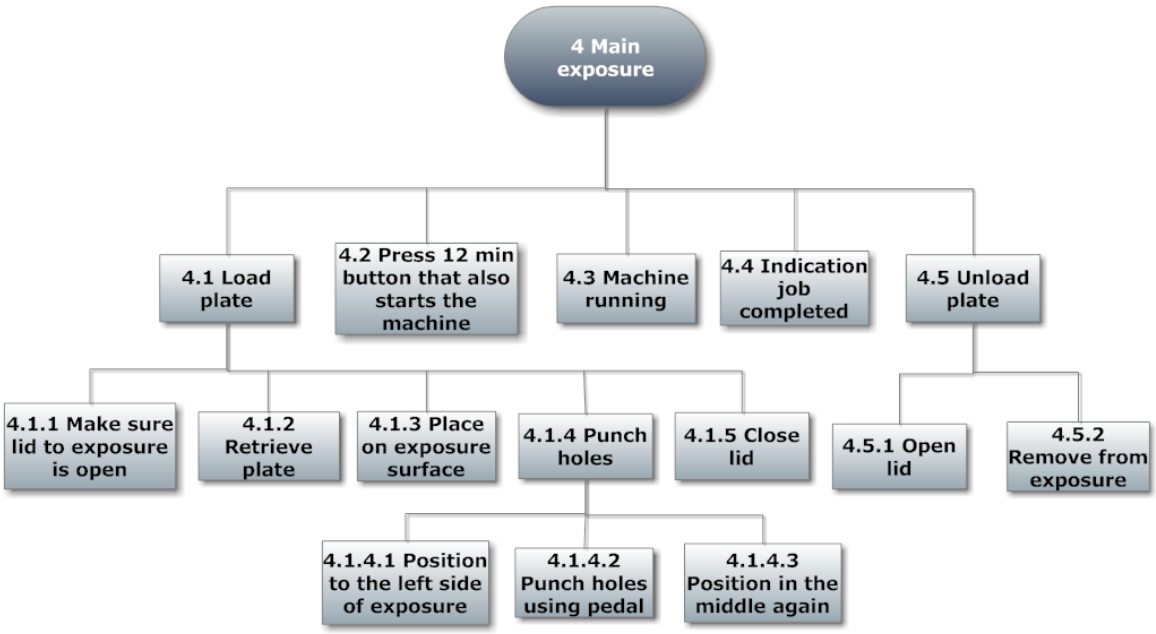


Figure 1.20 Hierarchical task analysis of main exposure in Lund

Issues

Since the plate no longer has the plastic cover it is more easily damaged by scratches and fingerprints. This makes the placing more critical since the operator needs to lean in far above the exposure surface when letting go of the plate. To avoid the plate from being damaged from repositioning it or corners from folding and scratching the surface it has to be let go as straight above as possible. The plate handling in this task step is therefore critical and has caused ergonomic issues in both back and shoulders. The punching task was actually critical in the beginning of these investigations but has since then been improved with a new puncher that leaves less waste material on the plate. This is an improvement much appreciated by the operators.

In Limburg, exposing is one of the most critical steps since the plate layout is planned while placing the films. As the lid of the exposure does not open completely the operator must stand bent when working which is ergonomically very bad for neck, back and shoulders. Furthermore having to stand above the exposure when placing the films could likely lead to more errors than when it can be done in the computer program. The computer program has barriers for placing files too close or too far apart and also contains information about the number of files that should be used.

In Limburg they have large issues with dust from the ceiling, damaging the clichés and therefore the films need to be cleaned both before placing them on the plate and afterwards. This step is time-consuming and uncomfortable for the operators.

Remedial strategies

The main exposure unit is experienced as robust and well performing and the most critical aspects of the machine are related to plate handling. Holding the plate with arms stretched out, at shoulder height, with a tight grip should be minimised and a slide-functionality as mentioned in the previous task should be investigated further. Today the exposure plays a beeping sound when it is ready to be emptied, in Limburg it open. This could be an idea to implement in Lund too, since it would not only be a useful indication but would also mean that the operators would not have to reach far above shoulder height every time they close the lid.

Due to the fact that Limburg has an analogue process, many small tasks are connected to the main exposure machine. With a digital process most critical tasks connected to this unit are eliminated. Rolling the plate into a roll as in Limburg makes carrying the plate easier and hence minimises plate handling.

5. Processor

In the processor the plate is treated with a solvent and brushes remove the unhardened polymer material, leaving only the floor and the exposed reliefs.

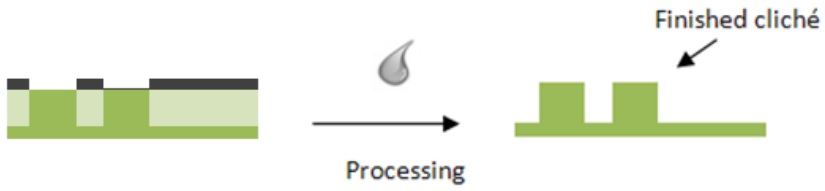


Figure 1.21 Illustration of processor

Task

After collecting the plate from the exposure it is placed on the processor table and loaded by fastening it to a fastener using the previously punched out holes along the side of the plate. To fasten the entire row the operators either have to stretch to reach or walk around to the other side of the processor. The fastener is then pushed into the machine and the machine is started. Two silent light alarms placed on the wall above the two processors, visible from the computer room, indicate when a plate is done. When the plate has been processed it comes out on the other end of the processor unit and placed on another in-built table, it is manually released from the fastener and carried to the dryers. If the dryers are full the plates are left on the processor's unloading area while waiting for an available drawer.

In Limburg the processor performs the same action as in Lund but the differing machine versions changes both loading and unloading. In Limburg there are no built-in tables and the plate is fastened on the fastener and then let hang before being pulled into the processor. When the plate has gone through the process the fastener occurs on the opposite side and an alarm located on top of the processor sounds and blinks. To unload the plate the fastener with fastened plate is pulled out manually onto a nearby table.

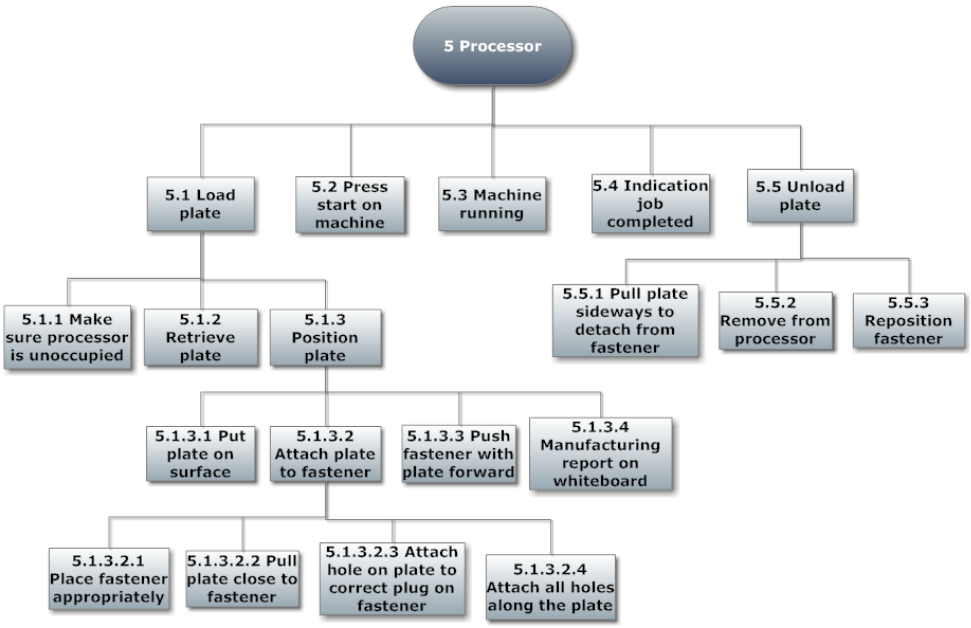


Figure 1.22 Hierarchical task analysis of the processor in Lund

Issues

It is very important that the processor is emptied before a new plate is loaded and processed. If not, they will collide and there is a high risk that both plates are damaged. In the step between the processor and the dryer the plates are highly sensitive and therefore the machine line layout should be optimised. In Lund this is not the case as the plates need to be transported through a small and turning passage. In Limburg however, the processor and dryer are placed in a line, close to each other.

Based on the investigations, using a fastener and holes to position the plate should be reconsidered. The major reason for this is that the operators either have to stretch to reach the entire row of holes or walk around the processor to fasten the second half. The handling with the fastener adds multiple time-consuming steps to the process. For example pushing the fastener with the plate forward to the entrance of the machine to be able to start processing, adds another step that is easily missed.

The ergonomic risks related to fastening the plate to the fastener are minimised in Limburg since the fastener is located by the table edge and closer to where the operators are standing. This, in combination with the plate being rolled together, means that the fastening can be done without stretching. On the other hand, the unloading of the plate from the processor have to be done by manually pulling it out, at a less favourable height than in Lund. This leads both to increased ergonomic risks and risks that the plate is damaged due to scratches from the machine exit. In Limburg they have tried to minimise these issues by constructing a home-made table which includes a fastener. With the fastener attached to a handle on the added table, they can stand on one side and pull without having to stretch across the table. Pulling out the plate along the table also avoids collision that causes scratches between the exit and the décor side of the plate.

Remedial strategies

Plates are left in the processor when there are no vacant drawers in the dryer. When there is a high pressure on productivity there should therefore be a possibility to store the plates between the processors and the dryers. As mentioned above the placement of the machines is especially important here because of the plates' high sensitivity. Today the space is too small to do any major layout changes but if possible there should be additional space included to avoid collisions and to allow comfortable plate handling. Furthermore the dryers should be placed directly connected to the two processors.

To solve the issue with the fastener it should be considered to use an automatic clamp. It should be possible to open the clamp and then start the process by pushing buttons on the machine interface. The clamp could also reposition automatically when the plate has been removed, solving the need to reposition the fastener. This solution would eliminate possible issues with waste material from punching ending up in printing and would be less time-consuming since it incorporates several tasks.

The home-made solution for unloading, created in Limburg, has been developed by the operators and is much appreciated there. Although, the machine in Lund that pulls out the plate itself and leaves it on a table surface to be collected is more ergonomically friendly and time efficient than either of the solutions in Limburg, also much due to a more favourable working height.

6. Dryer

In the dryer the polymer material dries after the processing. The dryers contain a number of drawers with warm airflow where the plates are placed.

Task

The operator opens an empty dryer drawer, retrieves the plate from the processor and places it in the drawer. In Lund the whole plate is moved from the processor to the dryers, but in Limburg the plate is first cut in two halves and from this step handled separately but placed in the same drawer. This is possible in Limburg because they use a manual cutting table. In Lund, when a drawer is loaded, the operator writes the time for when drying is finished on a whiteboard on the wall, in the field corresponding to the loaded drawer. In Limburg a count-down function on a small display next to each drawer is used instead. The display turns black when the plate is finished. When the plate is dried it is moved to the light finisher.

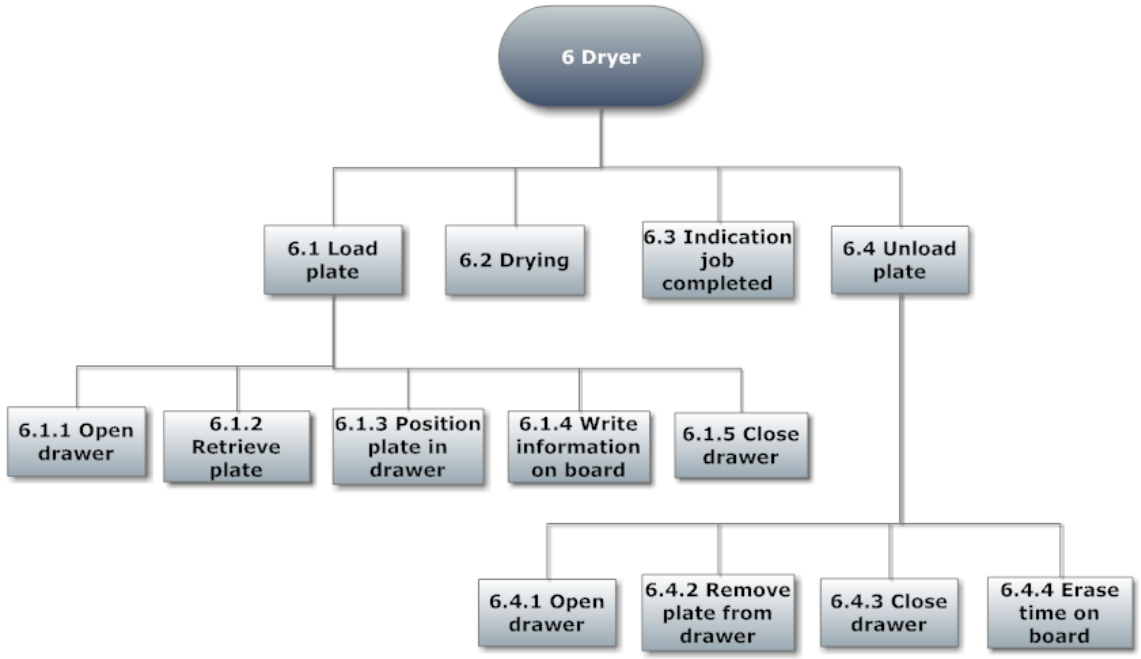


Figure 1.23 Hierarchical task analysis of dryer in Lund

Issues

When a plate is transported to the Dryer it is not only easily damaged, it is also very difficult to handle because it is sticky and slippery from the remaining solvent. Operators now use gloves for avoiding skin contact with the solvent but experience difficulties in holding on to the slippery plates when carrying it from the processor to the dryer. The slippery feature forces the operators to increase the strength of the pinching grip.

Today two different dryer versions exist. In Limburg they have two units of a later version and in Lund they have two older versions and one new. The updated dryers have drawers further down and the light finisher is placed on top. This makes both the highest and the lowest working positions unacceptable

and it has also been investigated and criticised by the occupational health care department. The lowest drawer is below what is recommended, and should therefore not be used, see *Theoretical Framework* (D:8).The high pressure on the drawers forces the operators to often use all drawers available.

To avoid corners from folding, scratches to the surface or other damages from repositioning the plate in the drawer, it has to be let go as straight above as possible which is difficult because the drawers cannot be fully pulled out. This forces the operator to place the plate as far in as possible first by stretching and bending over the drawer and then push and adjust it into place.

Additionally the plates are difficult to place because they are sticky after being processed and the surface of the drawers contains air holes which easily attracts dirt that makes it even harder to slide the plate. The surfaces in the new dryer drawers are better because dirt and remains have not yet accumulated to the extent that it is not possible to fully clean.

Remedial strategies

The difficulties in handling the plates after the processor could be minimised to some extent by a changed layout, placing the dryers in direct connection to the processor.

Another issue that needs to be solved is the height of the dryer drawers. Storing the plates in drawers on top of each other is a good way to minimise the space requirement, but the lowest drawers should be avoided. As the operators prefer the old dryers these measurements should be considered in new installations.

One advantage with the new dryers is the floor surface in the drawers that allows the plates to slide better. This indicates that the drawers have to be continuously maintained and exchanged when it is no longer possible to get them back to an acceptable state. As the plates in Limburg are cut in halves, placing them in the drawers are related to fewer issues. Unfortunately this cannot be done in Lund because the automatic cutting machine used here needs intact plates to be able to cut the clichés.

As mentioned above, Lund and Limburg have different strategies for keeping track on when to unload a plate. In Lund there is a possibility to use the same count-down functionality as in Limburg, but the majority of the operators interviewed expressed that they prefer using the whiteboards to get a better overview.

7. Light finisher

In the light finisher UVA and UVC light treat the plates to make them more resistant; the light also hardens the material further. One light finish drawer is placed on top each dryer.

Task

The operator opens an empty drawer, retrieves the plate from the dryer drawer below, places it and then starts the light finishing. When the plate is done the display turns dark. The operator then collects the plate and places it on the cutting table.

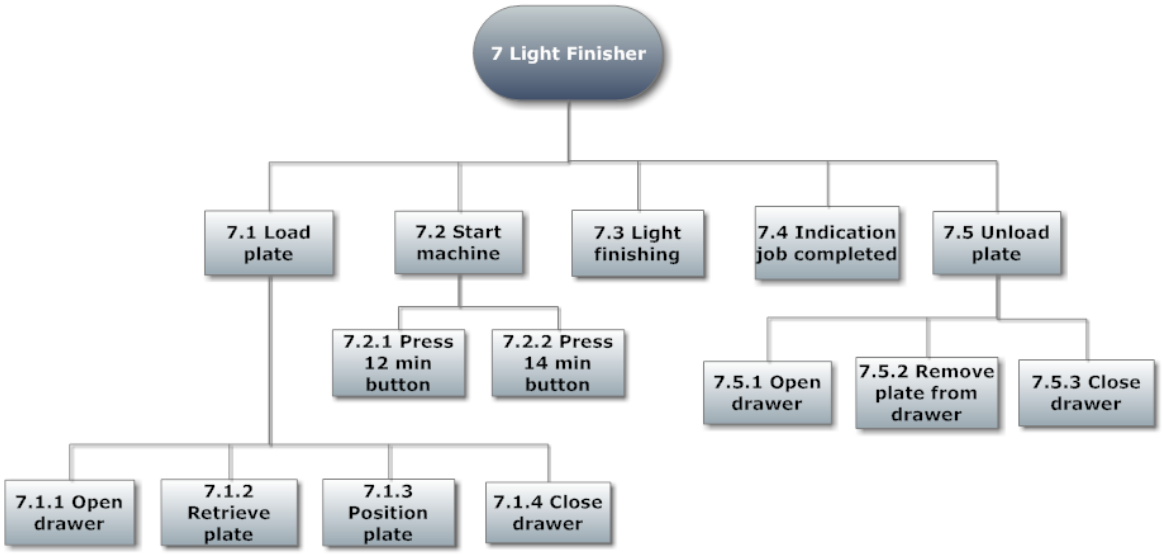


Figure 1.24 Hierarchical task analysis of light finisher in Lund

Issues

The operators experience the same kind of issues with the light finishers as with the dryers, especially with the later version. The difference is that the drawers instead are placed too high, which was also criticised in the occupational health care investigation mentioned above. The height forces the operators to work above shoulder height which should always be avoided, especially when carrying large and hard-to-handle items. Placing the plates is particularly critical since the positioning demands precision to avoid creases.

Remedial strategies

When talking about investing in a new Light Finisher it has already been discussed to place this drawer on a separate table instead of above the dryers. This is a good first step but the existing Light Finisher drawers should not be used either, and be moved as soon as possible.

In Limburg the same procedure is followed but as they have cut the plates in halves the handling is easier but still above shoulder height and a similar solution to the one discussed in Lund should be considered.

8. Cutting machine

In Lund, the cutting machine automatically cuts along the décor edges on the plate and delivers the finished clichés. In Limburg cutting is done manually.

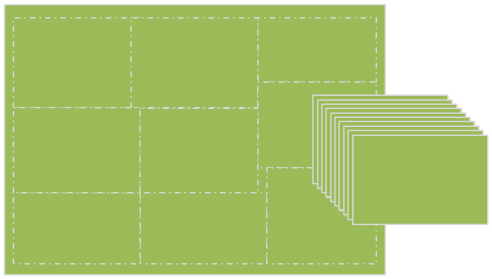


Figure 1.25 Illustration of the clichés after the cutting machine task

Task

In Lund the operator retrieves the plate from the Light Finisher and places it, backside up, on the cutting table. The backside is then cleaned to remove polymer leftovers and other particles and then turned again. From a computer the plate layout is chosen and the operator adjusts the cutter head by visually making sure that a cross on either side of the plate is detected and centred. The cutting machine then cuts out each cliché from the pattern sent from the computer (see figure 1.12). After cutting, the waste material is disposed and it is time for sorting.

If it is manually cut, as it is in Limburg, no computer file is used; instead each cliché is cut out manually. Waste material is disposed and, just as in Lund, sorting is initialised.

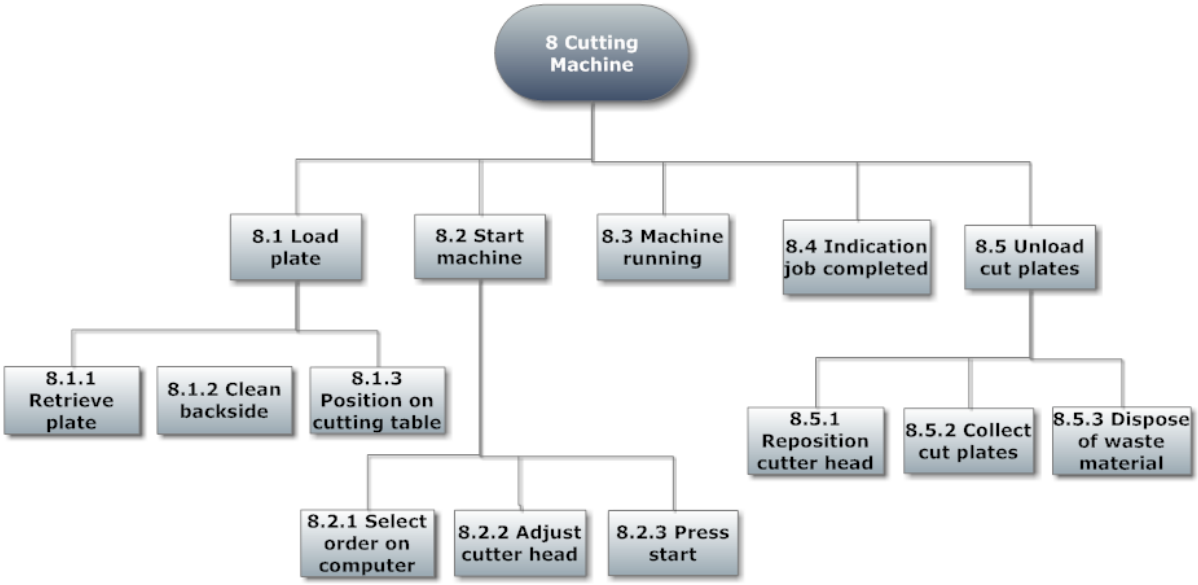


Figure 1.26 Hierarchical task analysis of Cutting Machine in Lund

Issues

Both in Lund and Limburg, cutting and sorting are done by one operator in each shift. The task is repetitive and demanding since the operator stands still for long periods of time and has to remain focused. Furthermore there tend to be a high time-pressure on this step to meet the productivity goals. Since the task is done manually by the operators in Limburg the issues become larger here and in interviews, cutting were acknowledged to be the task with the highest workload. The operator has to

remain focused for long periods of time to cut correctly along edges, detect previously done damages on the clichés and sort the clichés in the accurate mounting order. Often all dryers are full from the previous shift which increases the time-pressure further.

Ergonomic issues in this task are typically related to standing still for long periods of time. In Limburg a ventilation drum, causing a draft, is placed directly above the working area, which has lead to discomfort in neck and shoulders. To get a good view when cutting, the operators often stand bent, which causes additional discomfort in back, neck and shoulders. See *Theoretical Framework* (D:8) for a more thorough description of different working postures.

During the interviews and observations in Lund the operators also expressed that it was irritating having to reposition and turn off the cutter head before removing the cut plates.

Remedial strategies

The long periods of standing, especially in Limburg, should be reconsidered. Both Lund and Limburg have placed rubber carpets in front of the cutting machines to ease the negative effects in back, neck and shoulders from standing; however a varied posture is even more important.

Automation of the cutting could be a solution in Limburg to increase both efficiency and accuracy, but cannot be implemented as long as the process is analogue. However, if the manual table is kept it should be possible to adjust the height of the working surface to suit operators of different sizes. Today only men work in the production in Limburg, but with female operators height adjustment would be of even higher importance. To remain focused lighting should be sufficient and work rotation within a shift encouraged. Rotations are today done within only a few of the interviewed shifts.

The task of needing to manually reposition the cutter head after cutting in the automatic cutting machine has no purpose and could therefore be implemented in the machine functionality.

9. Sort cut plates

In the sorting task, the operator organises the clichés into order and places them in a pile together with the manufacturing report before handing the pile over to Cliché Mounting. As mentioned in *Process technology* (C), an order can be either a single print or a co-print. If it is a single print the same décor is printed on all lanes and if it is a co-print different décors are combined on each sleeve.

Task

If the order is a single print the lane placement of the cliché on each sleeve does not matter and the clichés only have to be sorted according to colour, i.e. all clichés belonging to one sleeve are placed together. Note that one sleeve represents one colour. If the order is a co-print the design order has to be considered for each lane on each sleeve. In Limburg sorting is officially done only once, directly after cutting. In Lund sorting is done in two steps, first in Cliché Making, directly after cutting and then a second sorting takes place in Mounting Preparations.

In the first sorting in Lund, the clichés are organised in colour order within each design. This means that single prints are sorted in the same order they will be mounted when they arrive to Mounting

Preparations (see figure 1.14). Co-prints however, have to be further sorted from *colours within each design* (see figure 1.15) to the specific lane order for each sleeve (see *Sorting* in *Mounting Preparations* below). Additional information about the sorting with a more thorough description can be found in appendix 3 (*In depth study: Sorting*).

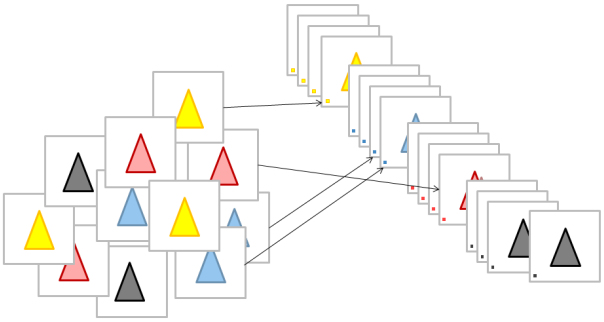


Figure 1.27 Sorting in Cliché Making, Lund and Limburg, single print

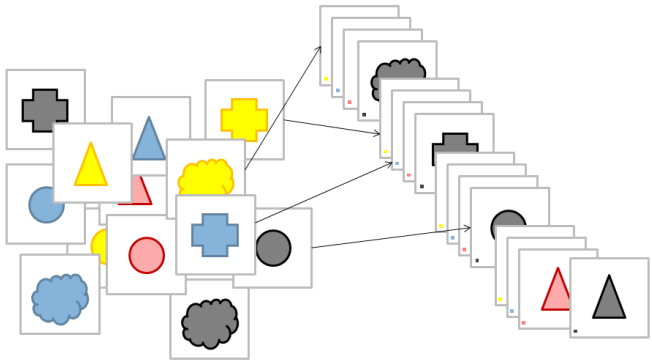


Figure 1.28 Sorting in Cliché Making, Lund, co-print

Sorting in Limburg also takes place directly after the clichés have been cut. They are then sorted in a similar way as in Lund but each sub-pile is separated by a post-it with the information of how many clichés are included of each design and what colours and lane they belong to (see figure 1.16). This makes it relatively easy for the person mounting to pick out the clichés needed for each sleeve. In a way this creates a sorting task for the Mounting operator as well but the Limburg personnel did not perceive it this way and felt the ultimate responsibility for sorting was on the operator by the cutting table.

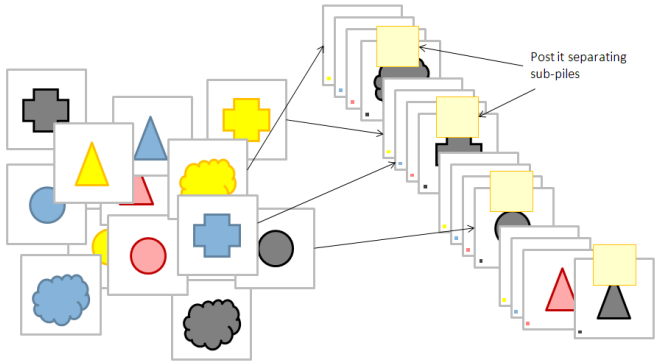


Figure 1.29 Sorting in Cliché Making, Limburg, co-print

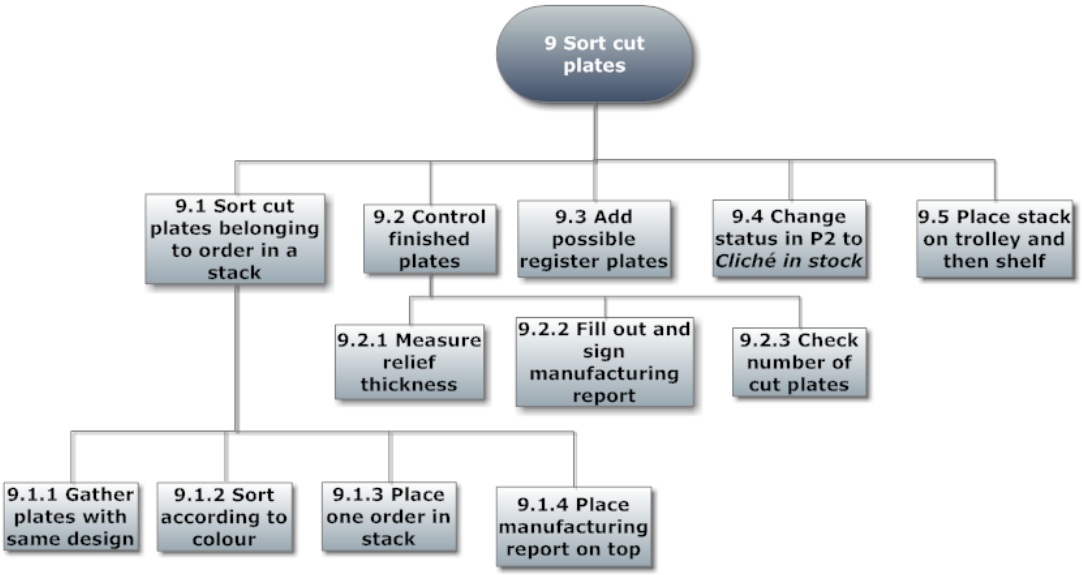


Figure 1.30 Hierarchical task analysis of Sort cut plates in Lund

In Lund the sorting is done according to the order printed on the manufacturing report, where all the information needed is provided. In Limburg a similar form is printed out, but containing only the information needed for sorting. Coloured markers are used to visualise how the lanes differ. If all lanes include the same design, only one colour is used. This provides only the necessary information in a structure that is easy to process.

For each order, one cliché is inspected by measuring the relief thickness, and finally blank plates are added to the pile. The manufacturing report is filled out and signed before the status is changed in P2 and the pile left for Cliché Mounting. In Lund the piles are stored in a rotating shelf system which can store the clichés for days depending on priority. In Limburg the pile is left on a trolley and directly moved into the Cliché Mounting area.

Issues

Issues similar to those in cutting should be addressed. Sorting is a task that involves standing for long periods of time and a high need to remain focused. The stickiness of the clichés makes the working height an even more important issue because force and stretching is needed to separate each cliché. The focus needed for both sorting correctly and managing to see the small numbers on each cliché also affects the task.

Another fact that has been identified as critical during the study is the number of sorting activities and the difference between the two sites. Based on observations of the entire Pre-press process and comparing Lund and Limburg, sorting only once, as in Limburg, is considered more time-efficient. Sorting proved to be a task of high interest in the predictive analysis and in the implementation of Easy ITS and hence many of the related issues are also discussed in appendix 3 (*In depth study: Sorting*) and will not be further discussed in this chapter.

Remedial strategies

The possibility of height adjustments, both for different individuals and different working positions, for example both sitting and standing, should be provided, discussed in *Theoretical Framework* (D:8). Job rotation within each shift should also be considered encouraged. Sufficient light or a light table avoid stretching and tired eyes. It should also be discussed if the workload put on the operator doing the cutting and sorting in Limburg is reasonable or if the work could be better distributed.

The sorting that Cliché Making does in Lund today is more time-efficient for them because they can quickly group each design by looking at the décors. If Pre-press is seen more as a full line including both Cliché Making and Cliché Mounting there would be a larger incentive to sort only once.

Since cutting is done manually in Limburg, the operators get an overview of the clichés already while cutting. Therefore the sorting can be initialised already directly after cutting each cliché instead of after a whole plate has been cut as in Lund. This makes sorting easier in Limburg compared to Lund.

2. Mounting Preparations

Below follows a layout for presenting tasks included in what is referred to as Mounting Preparations. Mounting Preparations includes serving the Mounting operators with all they need for mounting, i.e. sorting clichés, retrieving sleeves and preparing tape. The following task will be covered:

1. Retrieve cliché order
2. Sort cliché order
3. Prepare tape
4. Prepare masking tape
5. Retrieve sleeves
6. Finalise order
7. Take out finished sleeves

It should be said that the tasks included in Mounting Preparations are very differently distributed in Lund and Limburg. The HTA shown above refers to how the tasks are distributed in Lund whereas in Limburg many of the tasks instead belong to the Mounting operator.

1. Retrieve cliché order

In this first step the clichés with the highest prioritisation are retrieved from cliché storage to be prepared for mounting.

Task

First the operator detects the order with the highest priority in P2 and collects the corresponding pile of clichés from the rotating shelf system and the customer folder from the customer folder archive.

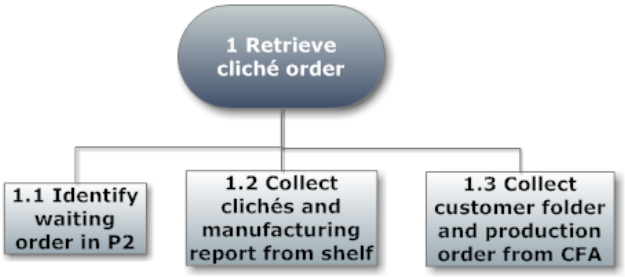


Figure 1.31 Hierarchical task analysis of Retrieve order in Lund

Issues

The issues identified in this step are mainly related to the use of P2. The error with the highest probability is a pop-up in P2 that causes an action delay. This error is categorised as latent as it is caused by the system and not the operators. There are also risks that prioritised orders are delayed due to choosing wrong orders, either because the inbox is not reloaded or orders with higher priority are missed. Other issues that might occur, but are judged to be of low probability, are related to finding folders and material.

Remedial strategies

Clear colour coding would improve the interface of P2 and make order selection easier. Pop-ups disrupting the work because someone else is working within P2 should if possible be avoided. Normally operators are not working with the same order at the same time and therefore it should not matter if the system would remain unlocked when other statuses are changed.

2. Sort cliché order

In this step the clichés are arranged in piles, checked and prepared to be mounted.

Task

First a checklist is written by hand by the operator who extracts information about the mounting order from the manufacturing report. In Lund, after the clichés are cut out and sorted for the first time, the clichés are organised in colour order within each design. This means that single prints are already fully sorted and only have to be checked in this step. Co-prints however, have to be further sorted from

colour order within each design to the specific lane order on each sleeve (see from left to right in figure 1.19). The colour is written on the first cliché in each colour.

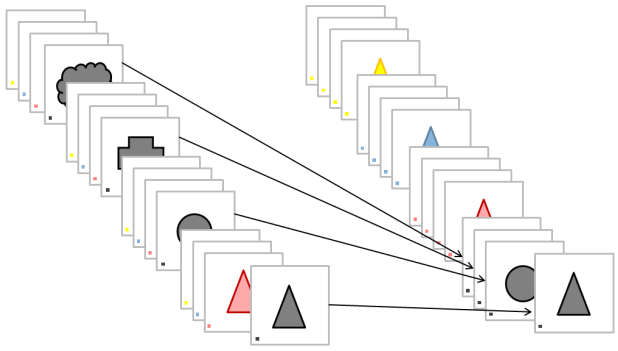


Figure 1.32: Sorting in Mounting Preparations, co-print

The factory in Limburg does not use handwritten checklist, instead the information on the manufacturing report has been rearranged to be sufficient.

In Lund, lane, month and year marks are cut off, using a tong, on the clichés belonging to the technical colour. Finally a last check is done, making sure the sorting is correct and that a slitting line (guideline for slitting) and possible empty plates are included in the material sent to the mounting machine.

In Limburg the main sorting takes place directly after the plate is cut and is therefore not included in this particular task. The second sorting activity is in Limburg done by the Mounting operator.

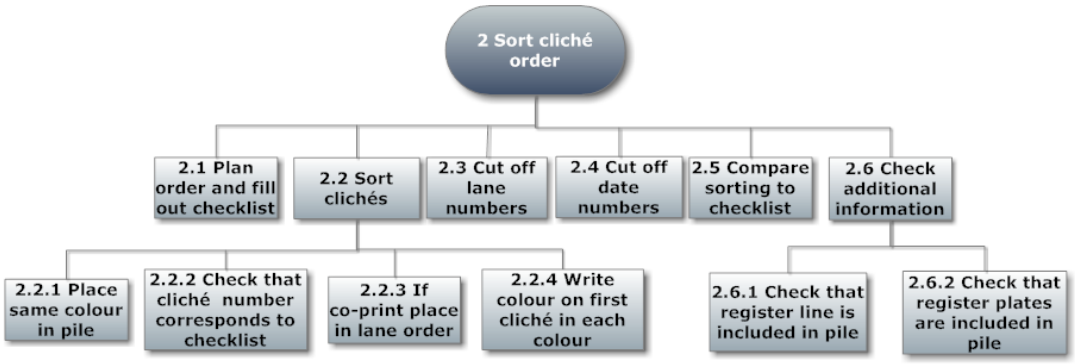


Figure 1.33 Hierarchical task analysis of Sort cliché order in Lund

Issues

A range of critical issues were detected in this step, especially in Lund. For starters, errors do occur when the handwritten checklist is filled out. The space to write the numbers on the manufacturing report is limited and wrong numbers easily written. Even if the checklist is correct the operators can omit to detect previously incorrect sorting and make own errors when arranging co-prints. Multiple critical errors have been identified when removing the numbers from the clichés. There are risks that wrong numbers are cut off, either that the wrong numbers are cut off the cliché or that numbers are

removed from the wrong cliché. The most critical error is that cut off numbers get stuck to the cliché surface and leave marks in printing.

Sorting proved to be a task of high interest in the predictive analysis and in the implementation of Easy ITS and hence many of the related issues are also discussed in appendix 3 (*In depth study: Sorting*) and will not be further discussed here.

Remedial strategies

Sorting is a critical task since it is important to stay focused. In the process in Lund today sorting is done in multiple steps which give the operators many chances to detect errors, but at the same time there is less pressure on each operator to make sure they sort correctly. It would most likely be beneficial for the process to only sort once and as mentioned above it would be a larger incentive to do this if Pre-press is seen more as one line including both Cliché Making and Cliché Mounting.

Today the operators in Lund have their own remedial strategy if the wrong numbers are cut off. If an incorrect number is cut off they can instead cut off all numbers but that number. Numbers getting stuck has been minimised by using tongs instead of knifes, but it is still an issue. Tongs have also decreased scratches on the clichés. The task of cutting off the numbers could be excluded by adding this information to the clichés belonging to the technical colour, already in the imager. This way the clichés belonging to the technical colour could have information included on its décor. Including the information already in the décor would affect the sorting since the lane order on the technical colour would now matter, even for single prints. The issues and remedial strategies discussed in this task are further developed in appendix 3 (*In depth study: Sorting*).

3. Prepare tape

In this step the tape used when mounting the clichés is prepared.

Task

In Lund tape is punched out in sizes corresponding to the cliché formats, using punch templates. First tape is pulled off the role, cut and placed in piles of 5 tape layers. The pile is then punched and waste material is thrown away. The procedure is repeated until enough tape to mount the full order has been prepared.

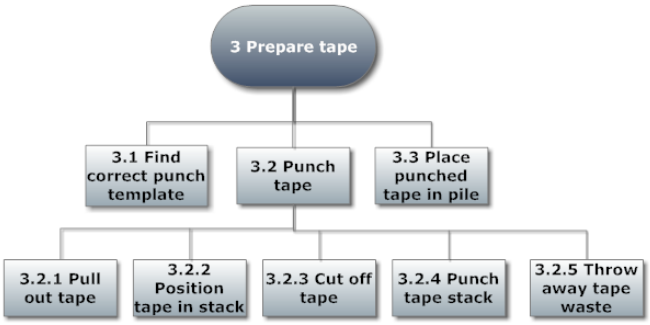


Figure 1.34 Hierarchical task analysis of Prepare tape in Lund

In Limburg wider tape lanes are used and mounted directly onto the sleeve from the roll, using a semi-automatic taping machine.

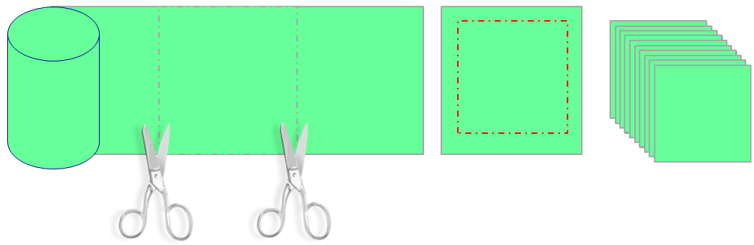


Figure 1.35 Illustration of the tape preparations

Issues

The largest issue when preparing the tape is using a skew punch template, and therefore latent. Skewly punched tape can still be used if adjustments are made in mounting. Another issue worth mentioning is the large spill due to punching out tape compared to mounting tape lanes directly from a tape roll.

Remedial strategies

The punching in itself works well, partly because of directions on how many layers of tape can be punched at a time. Skew tape can be avoided if the quality of the templates is regularly controlled and worn-out ones are replaced. This has improved in Lund, however the whole process could be updated by considering automatic tape feeding that cuts off the tape at a certain length to avoid unnecessary spill. The need for tape pieces of the same format as the clichés could be questioned and the possible use of wider tape widths investigated.

4. Prepare masking tape

In this step masking tape with information about the sleeves is prepared.

Task

In this step the operator retrieves different colours of masking tape and places them on a green plate as a preparation for the Mounting operator. On each piece printing order number and colour number, related to the corresponding sleeve, are written. In mounting a tape piece is attached to each sleeve and the information is later needed in printing.

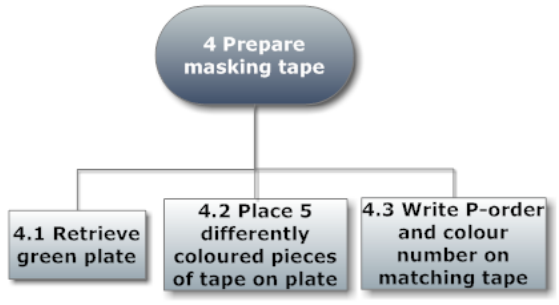


Figure 1.36 Hierarchical task analysis of Prepare masking tape in Lund

Issues

No critical issues have been discovered in this step and all potential errors are considered to have low probability.

Remedial strategies

Even if no issues have been discovered in this step the necessity of preparing the tape beforehand are questioned. One suggestion is that the information instead is written by the Mounting operator to avoid mixing up the tape pieces in later steps.

Limburg uses regular masking tape and information is added by the Mounting operator, thus Limburg may be helped by the system used in Lund with coloured tape.

5. Retrieve sleeves

In this step the correct sleeves are retrieved.

Task

The manufacturing report is checked to find out which sleeve types that are the next to be mounted. The sleeves are retrieved from the sleeve storage and brought to the mounting area using trolleys. The sleeves used are then reported on the computer.

In Lund the sleeve storage consist of a large shelf where sleeves are placed on horizontal shafts. For transport to the mounting area the sleeves are placed on horizontal shafts on a trolley. For smaller sleeves a vertical sleeve trolley is used.

In Limburg sleeves are stored on the floor or in a room across the production hall. They are brought to mounting using vertical sleeve trolleys and in mounting they are stored either on the floor or on a horizontal sleeve trolley on which shafts are placed significantly higher than on the one used in Lund.

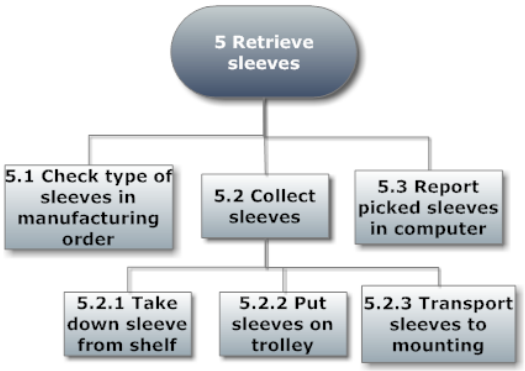


Figure 1.37 Hierarchical task analysis of Retrieve sleeves in Lund

Issues

This task involves heavy manual handling. The shelf in Lund is very high and sleeves far up have to be retrieved using a ladder. This forces the operator to stand on the ladder platform while reaching to dismount the sleeve from the shelf and then climb down while holding the sleeve. Loading the sleeves

onto the trolley also has ergonomic implications since the low shafts are placed too low and the higher shafts too high.

The heavier sleeves can weigh up to 30 kg and handling them is difficult for the operators for two reasons. First because of the weight in itself and secondly it is hard to get a good grip and balance the sleeve, much due to its long shape. To transport the sleeves to the mounting area the operators push the trolley in front of them and cross a path for automatic carriers. Here there is a risk that the operator runs into someone else, runs over his or her own foot with the trolley or collides with an automatic carrier.

Another issue is that sometimes the correct sleeve types are not available. This is a latent issue that occurs when many prepared orders in a row requires the same sleeve type.

Manual handling proved to be the second task of high interest in the predictive analysis and in the implementation of Easy ITS and hence many of the related issues are also discussed in appendix 4 (*In depth study: Manual handling*) and will not be further discussed in this chapter.

Remedial strategies

The manual sleeve handling needs to be improved. To begin with the shelf for sleeve storage in Lund is far too high. Using a rotating shelf system that delivers the sleeves on an appropriate height should therefore be considered. Furthermore the trolleys used in mounting today are not appropriate either. They should be redesigned and the lower arms should be removed and the higher considered. It should instead be investigated if the trolleys could be made wider to make sure they have room for enough sleeves. The trolleys in Lund have been modified with a protective edge along the lower edge that eliminates the risk of running over someone's or one's own foot. If there is a possibility to re-organise the factory layout carrier paths and walking paths should not cross. To avoid that required sleeves are not available communication between the operators is crucial.

Additional recommendations and remedial strategies to minimise and improve manual handling are discussed in appendix 4 (*In depth study: Manual handling*).

6. Finalise order

In this step the final preparations are done for the order to be ready for Mounting.

Task

In this step the manufacturing report is signed and is together with the prepared cliché pile placed in a cabinet next to the mounting machines. To indicate where the orders are placed the last four numbers of the order number is written in a corresponding box on an adjacent whiteboard. Finally the status in P2 is changed to *Cliché Sorted.*

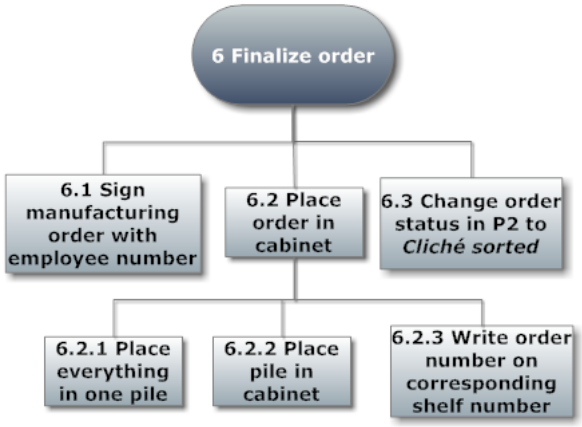


Figure 1.38 Hierarchical task analysis of Finalise order in Lund

Issues

The only critical issues detected in this task are omitting to change the P2 status or changing it to an incorrect status. Additionally it is important that the operator makes sure that all material is added to the cliché pile.

Remedial strategies

As mentioned in previous tasks, clear colour coding would improve the P2 interface and facilitate order selection.

7. Take out finished sleeves

In this step, finished orders are delivered to printing.

Task

The preparing operator identifies if a full order has been mounted and transports the trolley with sleeves to the printing storage area.

Figure 1.39 Hierarchical task analysis of Take out finished sleeves in Lund

Issues

With communication between the operators there is a very small risk that a trolley with an incomplete order of sleeves is removed.

Issues identified with this task are related to transporting the sleeve order from the mounting area; issues very similar to those found when transporting the sleeves to the mounting area. Therefore the reader is referred to task 5 *Retrieve sleeves* above and these issues are not discussed further here as well.

Remedial strategies

For remedial strategies the reader is referred to task 5 *Retrieve sleeves* above.

3. Mounting

Below follows a presentation of the tasks included in what is referred to as Mounting in this study. The tasks involved in mounting the clichés are organised in the following steps:

1. Retrieve order
2. Load sleeve
3. Tape mounting
4. Cliché mounting
5. Additional mounting
6. Check completed sleeve
7. Unload sleeve
8. Report completed order

1. Retrieve order

In this step the operator makes the final preparations before the actual mounting begins.

Task

In P2 the operator locates the order with the highest priority, retrieves the order pile from the cabinet and double-checks the sorting. The Microflex (the mounting machine) is assigned with a recipe that decides the steps the mounting machine moves between each lane when mounting (based on package size, sleeve type and number of lanes). Finally the operator checks that correct sleeves have been retrieved.

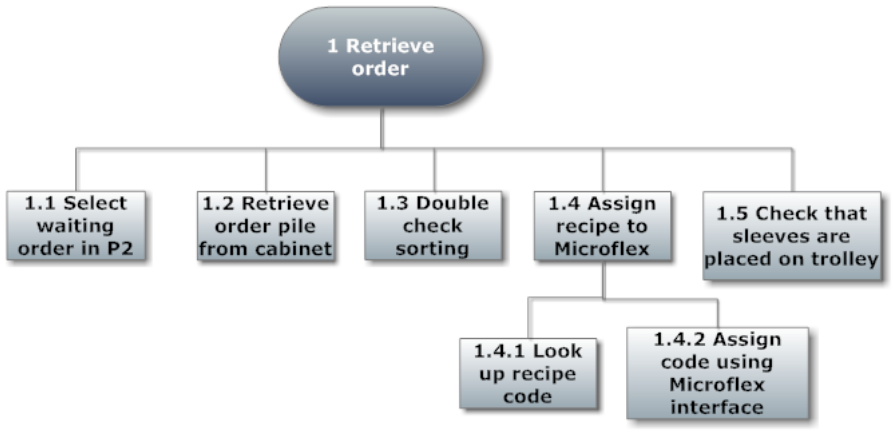


Figure 1.40 Hierarchical task analysis of retrieve order in Lund

Issues

Issues with identifying the correct waiting order occur with this task as well. The double checking of the sorting is an important task since this is the last chance to detect previously done errors. Missing errors or omitting to check the sorting has been identified as critical since this step is sometimes omitted and errors remaining or created here will likely follow all the way to printing. The interface of the Microflex, is for some functionalities, located above shoulder height which causes an inconvenient working posture for the operator.

Remedial strategies

Even if sorting would be done only once, a thorough double check needs to be done. The issues related to the Microflex has been minimised with an installation of a rubber spline at waist height, this removes some of the machine interactions taking place above shoulder height. Nonetheless it should be investigated if the display could be placed further down.

As mentioned in previous tasks, clear colour coding would improve the P2 interface and facilitate order selection.

2. Load sleeve

In this step a sleeve is loaded onto the Microflex machine.

Task

The operator opens the shaft end with a button that also turns on air compression along the shaft on which the sleeve is pushed onto. In Lund the sleeve is retrieved from a nearby horizontal trolley and in Limburg sleeves are placed on the floor next to the mounting machine. The air compression facilitates pushing the sleeve onto the shaft and then the position of the sleeve is adjusted by fixating keyholes on the sleeve edge to an indication on the machine. Finally the shaft end is repositioned and the sleeve fixed.

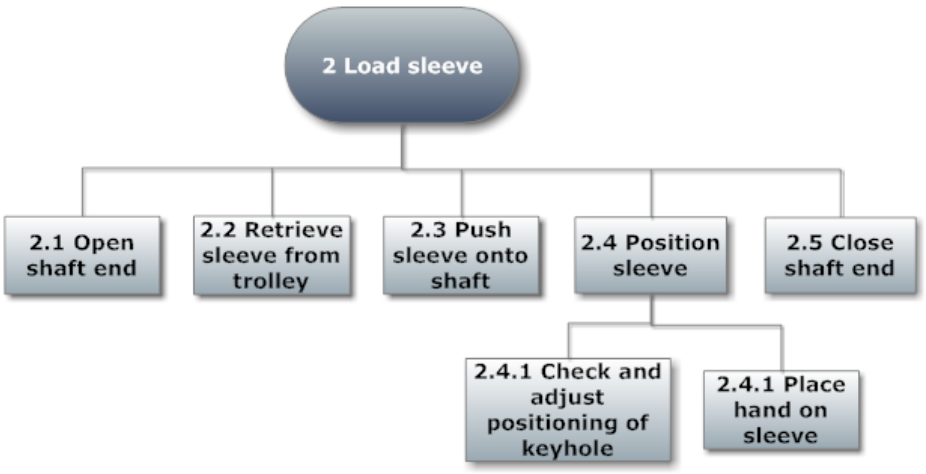


Figure 1.41 Hierarchical task analysis of Load sleeve in Lund

Issues

Critical issues have been detected when moving the sleeves from the trolley and onto the shaft. There is a high risk for discomfort in back and shoulders when lifting the sleeves, especially from the lower levels of the trolley, and when pushing the sleeve onto the machine shaft. The task is harder for worn out sleeves since they cause increased friction between shaft and sleeve. Additionally this task forces the operator to twist wrists and hands when lifting the sleeves.

Remedial strategies

To decrease friction between sleeve and shaft it is important to regularly maintain the sleeves and replace or fix sleeves with scratches and damages inside. The keyholes should also be maintained to facilitate accurate positioning.

Using a horizontal trolley, as in Lund, is preferable since twisting movements are avoided when moving the sleeves from trolley to shaft. All issues connected to manual handling of sleeves, such as lifting sleeves off and onto the different trolleys, are discussed further in appendix 4 (*In depth study: Manual handling*).

3. Tape mounting

In this step the surface of the sleeves are covered by a layer of tape.

Task

Lund and Limburg have different procedures for taping the sleeves. In Limburg it is done on a separate semi-automatic tape mounting machine and in Lund the machine used for mounting is used for tape mounting as well.

Where the mounting machine is used the tape is correctly positioned using the camera. The edge is first positioned along the keyhole line on the sleeve, i.e. a line along the surface area. Then the end of the tape is held straight out to avoid air bubbles, and a roller is rolled on the tape until the loose end points straight down. The roller is then rested on the table and pressure is applied while the operator holds the edge of the plastic cover on top of the tape and rotates the sleeve by pushing a foot pedal. Afterwards the machine is positioned to mount the next piece of tape by pushing the rubber spline on the machine.

In Limburg wider tape lanes are used and mounted directly onto the sleeve from the roll. A semi-automatic taping machine is used which facilitates the manual mounting of the tape rolls. The operator positions the tape edge on the sleeve and then the sleeve is automatically rotated and the tape attached. The tape is then carefully cut off using a knife and the overlap tape is removed.

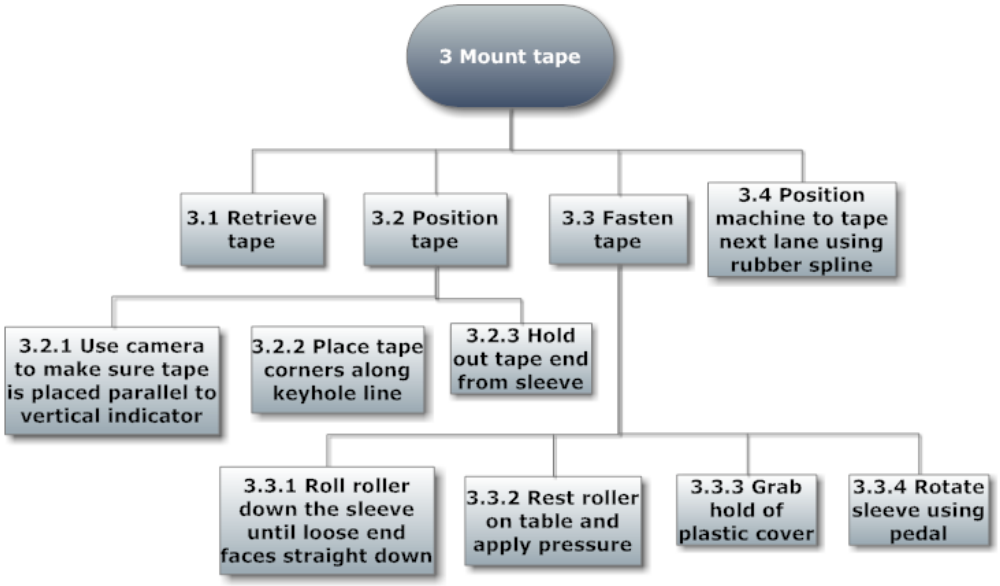


Figure 1.42 Hierarchical task analysis of Mount tape in Lund

Issues

Air bubbles under the tape have long been an issue but have decreased with the implementation of a standardised working procedures and the use of rollers; however it is still critical to firmly hold out the tape edge from the sleeve surface to avoid creating air bubbles. When rolling the roller over the tape piece it is important that the roller does not touch a tape surface without plastic cover. This can lead to that dust and material from the roller gets transferred onto the tape and thus causes irregularities that might affect printing.

To rotate the sleeve in the mounting machine the operators hold down a foot pedal. Since they do not stand evenly balanced when doing this it causes an uneven working posture which can lead to repetitive strain injuries (RSI) or work related upper limb disorders (WRULDS), discussed further in *Theoretical framework* (D:8). The operators have on many occasions expressed that this unbalanced working posture is straining.

For the taping process in Limburg few issues were detected in general, which could be due to time limitations for observations and interviews. To be noted is that the tape used in Limburg was not the same as in Lund, which may have been the reason that the tape machine appeared to be working well. Limburg uses a thinner tape which makes overlaps a smaller issue.

Remedial strategies

In Lund the working procedure has been updated by a WCM team to try to solve the issue with air bubbles. Therefore the suggested remedial strategy is to follow existing recommended procedures. The recommended procedure also works to minimise dust getting stuck on the roller and then on the surface of the clichés.

It should be considered if the pedal function is sufficient or if it would be possible to incorporate more functionality on waist height, such as for example using the rubber spline when rotating the sleeve.

4. Cliché mounting

In this step the clichés are mounted onto the sleeve.

Task

In this task clichés are first retrieved from the sorted pile and positioned by positioning the microdots (indicators similar to crosses) by comparing them to crosses on a provided camera image. First the left microdot is positioned both horizontally and vertically and then the right microdot only has to be positioned by adjusting it vertically. The operators apply pressure on the dots and roll over them with a roller. Then they rest the roller on the mounting table and apply pressure while rotating the sleeve using the foot pedal. Finally the machine is repositioned by pressing the rubber spline to mount the next cliché.

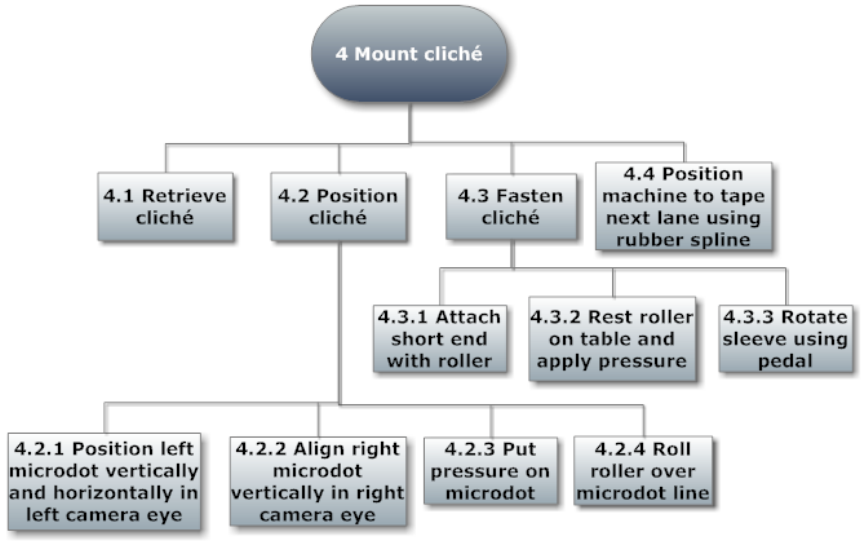


Figure 1.43 Hierarchical task analysis of mounting clichés in Lund

Issues

High precision mounting is one of the most important requirements and even though the operators are good at what they do it is still a task requiring high focus and concentration. For example summer workers rarely do this task and instead only do the preparations for mounting. Most critical issues identified in this step are related to positioning the microdots incorrectly. Additionally it is important that the operators are observant and mounts the clichés in the right place. Even if sorting has been done by another operator before the Mounting operator receives the pile of clichés, the final step is done here and thus has to be done correctly. Finally the same issues related to tape mounting regarding the foot pedal are just as critical in this step.

Remedial strategies

As just mentioned the task itself is critical and it puts a high pressure on the operators to mount correctly. Cameras and standardised procedures have been implemented to facilitate the process and some of the operators did express that they were pleased with the solutions today, and that they work well compared to what they worked with before. As mentioned in remedial strategies for tape mounting an alternative to using the foot pedal to rotate the sleeve should be investigated. To minimise errors further, automating this task is another solution.

5. Additional mounting

In this step, slitting line and masking tape are mounted.

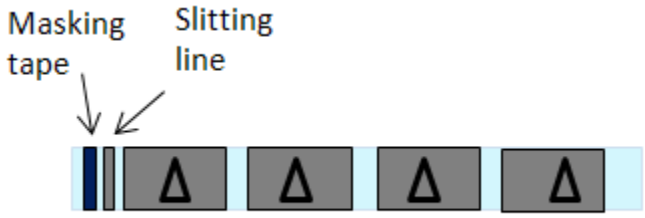


Figure 1.44 Illustration of placement of masking tape and slitting line

Task

First a masking tape piece with information about the mounted clichés is attached around one edge of the sleeve. The information has been written on the tape in Mounting Preparations and hence the operator here chooses the corresponding tape for each sleeve.

For the technical colour sleeve the operator also mounts a slitting line (guide line) that will indicate the positioning in the slitter (a later process step, not in Pre-press and hence not covered in this Master Thesis). This line is a made by the same material as the clichés but less than one cm wide. The mounting machine includes a recipe for mounting a slitting line as well, but the operator has to cut it in an appropriate length before fastening it to the sleeve.

In Limburg only one colour of masking tape is used and the mounting operator writes the numbers himself instead of receiving all pieces prepared. The slitting line is fastened in the same way in both Lund and Limburg.

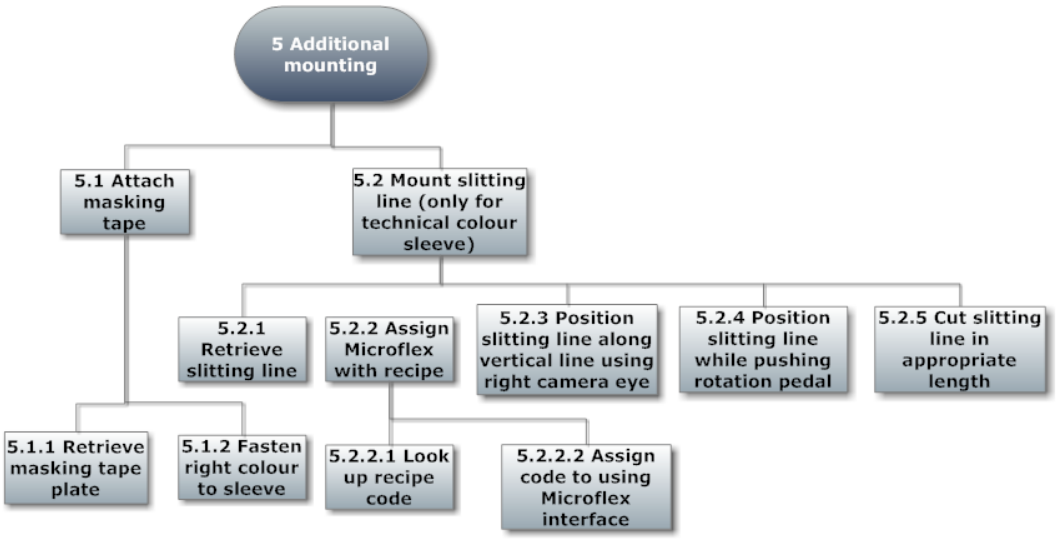


Figure 1.45 Hierarchical task analysis of additional mounting in Lund

Issues

The operators have not expressed any issues with the mounting of the masking tape. In Lund they find there is no actual point of using coloured tape for them, but express that it is useful for the operators in Printing. In Limburg the mounting operator writes the information on the sleeve himself which could be a good way to make sure, and add an extra check, that the right clichés have been mounted to the sleeve.

During the analyses in both Lund and Limburg, it has become clear that the adding of the slitting lines is related to a range of issues. Firstly it has to be mounted on the correct sleeve, the technical colour sleeve. This can be checked by verifying that the sleeve has a cliché with a photocell but for co-prints there is sometimes more than one sleeve with photocells, then the slitting line should be mounted on the sleeve with the darkest colour.

The next critical issue is asquint mounting of the line, which causes issues in Slitting. This issue has been expressed by the operators on multiple occasions and detailed recommended procedures have been created for this task. Since there is only a small contact surface between the slitting line and the tape there is also a high risk that the slitting line edges are not completely fastened and need to be re-mounted. This issue is most often detected by the operators but if not it causes issues in Slitting. Cutting the slitting line in an appropriate length has not been experienced as a critical task by the operators interviewed in this study. However it has been raised on multiple occasions in education materials.

Finally the same issues raised previously about the foot pedal for rotating the sleeve and about using the Microflex interface above shoulder height are relevant here as well.

Remedial strategies

As mentioned above, writing the information about the sleeve on the masking tape just before attaching it to the sleeve could be a good way to double-check the mounting.

To be sure that the slitting line is mounted on the correct sleeve, with the correct length at the right angle, it could be included on the cliché furthest out on the technical colour sleeve. This would make one cliché on each order wider than the others which would need to be included in the Microflex recipes. Additionally the lines would automatically have the appropriate length and cutting would no longer be necessary. Finally it would make mounting more efficient since one step could be excluded.

If the above solution is not possible another suggestion is to cut the slitting lines in appropriate lengths already in the cutting machine.

Additionally avoiding the foot pedal and redesigning the Microflex interface to be used on a lower height should be considered.

6. Check completed sleeve

In this step the sleeve is checked.

Task

In this step the operator checks the sleeve to make sure that the mounting is done correctly and that all features have been added. The sorting is not checked in this step, instead the operator checks that the slitting line, date and lane marks are included, before signing the masking tape. Before the manufacturing report is signed a visual check is done to make sure that the stepping is correct and that there are no overlaps or loose cliché edges.

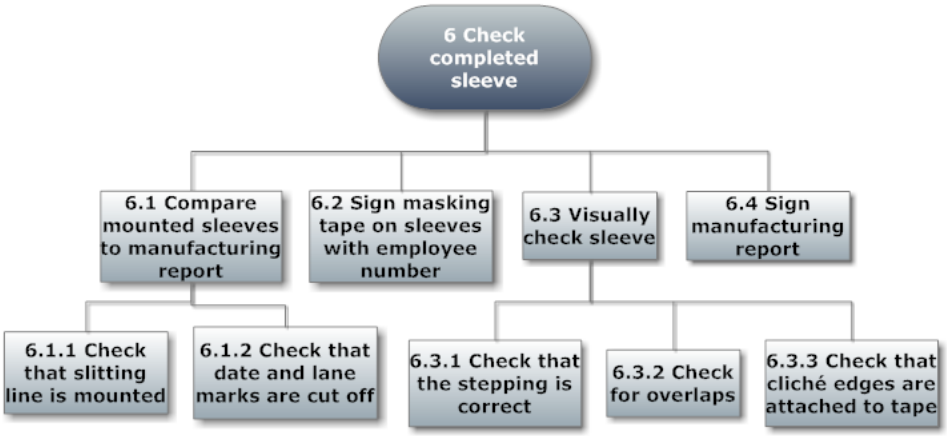


Figure 1.46 Hierarchical task analysis of checking of completed sleeves in Lund

Issues

This step is done to capture previously done mistakes. All errors identified in this task are either categorised as an omitted action or a violation, since not performing the action can be compared to consciously performing the task incorrectly. The checking tasks are time-consuming and in many aspects difficult to motivate, since if done correctly to start with it would not need to be done.

Remedial strategies

To verify that the correctly mounted sleeves are delivered to printing it is important to verify who has the responsibility to perform the check. One way to do this, which mostly already is done, is to clearly define on the manufacturing or delivery report who performed the control and thereby takes responsibility for the quality and usability of the end product.

Additionally, if the operator attaching and signing the masking tape also writes the printing order number and the colour number, this step could be done simultaneously.

7. Unload sleeve

This task is similar to *Load sleeve* and therefore creates the same issues and remedial strategies identified for loading sleeves. For that reason the reader is referred to *Load sleeve* above (Mounting, task 2).

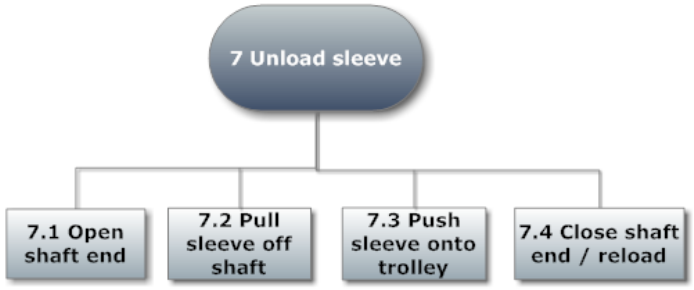


Figure 1.47 Hierarchical task analysis of unloading of sleeve in Lund

8. Report completed order

In this step the order is finalised by the operators in mounting before it is sent to printing.

Task

In this step the manufacturing report is placed in a folder that will remain in the Pre-press department, making it possible to trace issues identified in printing or further along in the production process. Since information needs to be delivered to printing as well, a new delivery report is retrieved, filled out and signed. This report is then placed in the customer folder which travels to printing with the sleeve trolley. Finally the order status in P2 is changed to *Ready to start*. The sleeves for the order are now ready to be transported to printing.

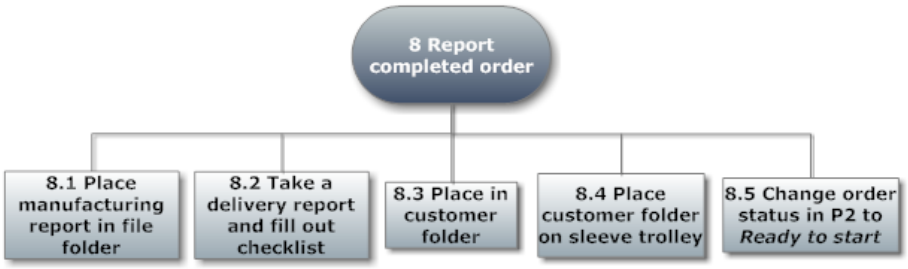


Figure 1.48 Hierarchical task analysis of reporting of completed order in Lund

Issues

The only critical issue identified in this task is the risk of changing to the wrong status in P2. If this is done there is a risk that the order is delayed because the information about the ready order is not sent to printing.

Remedial strategies

For many issues identified in the analysis a suggested remedial strategy is to connect the manufacturing report or delivery report to P2 so that the information given on the report could be entered into the computer program instead. This would minimise the amount of paperwork and would function as a barrier to make sure that all necessary information has been entered before the order is sent to printing. In different process steps P2 could for example require certain information to be able to change status. This solution should however be discussed further with the operators because having the information on a paper is sometimes preferred. If keeping the paper forms they should be looked through and all unnecessary information should be removed.

Appendix 2
Process description: Easy ITS

The new Easy ITS production line will here be described in terms of process steps, identified issues and remedial tasks or recommendations. The line includes the following tasks:

10. Plan plate layout
11. Imager combi (back exposing, imaging, main exposing)
12. Cutting machine
13. Sorting
14. Tape mounting
15. Plate mounting
16. Processor (processing, drying, light finishing)
17. Finalise order

1. Plan plate layout

In the first step of the Easy ITS process, orders are still planned in a similar way to how it is done in Pre-press Lund.

Task

To start up an order the operator selects the most prioritised order from P2 and then downloads digital files containing the décors belonging to this order from the software program *Backstage.* The files are then ripped into another software program called *Merge* where the décors from different orders are positioned and combined on large plates, optimised with regards to both efficient plate use and due time. Finally a manufacturing report is printed and the information about the plate layout is exported to be used in the Imager combi and the cutting machine.

During the evaluations of the existing process it was suggested to start to add date and lane numbers on the clichés already when imaging. To do this, one suggestion is to add this information to the design file already when planning the plate layout.

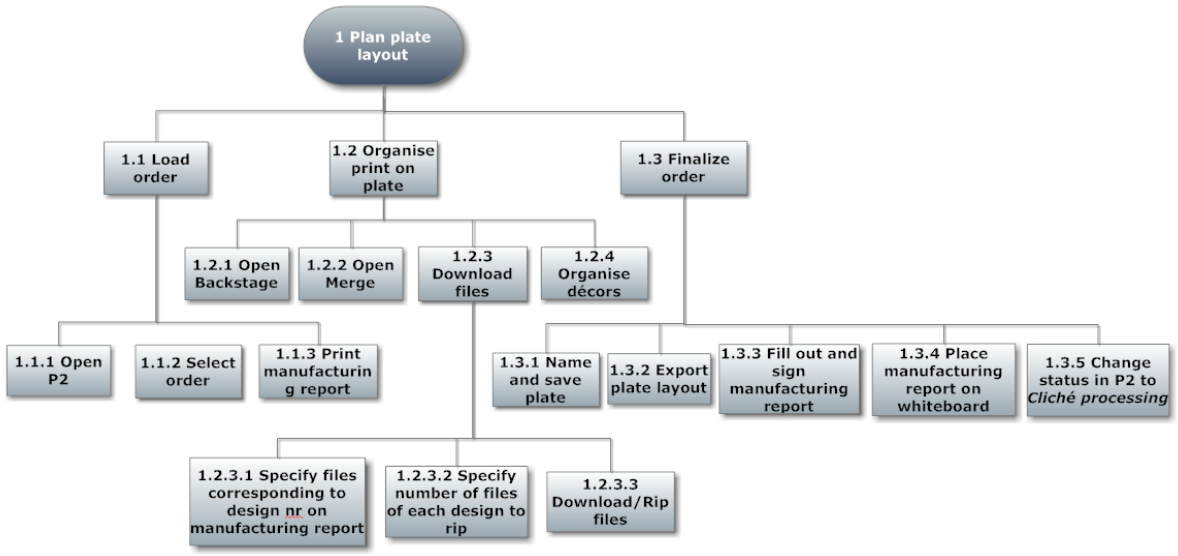


Figure 2.1 Hierarchical task analysis of Plan plate layout in Easy ITS

Issues

The largest issues in this task are linked to the computer program P2 that gives information about what orders to process. The program does not update on its own which can lead to that non-prioritised orders are chosen. Furthermore pop-ups occur when someone else is working within the program which causes irritating action delays for the operators. Finally P2 contains long lists of orders and the status of the orders are labelled only with text (e.g. Cliché processing, Cliché in stock, etc). As a consequence the wrong order is sometimes chosen or an order is given an incorrect status.

The operators have not experienced issues with organising the plate layout in the digital Pre-press process in Lund and since this task will remain very similar, the transition should be quite painless. It takes some time to learn how to best combine décors on a plate but once this is learned the task is not critical. Concerning the transition from analogue to digital operators feel that the digital process has been well translated from the manual of placing analogue films on the plate and that the same knowledge can be used.

Through the in depth study of the sorting process and how it will change with the new process a new sorting procedure was suggested, see appendix 3 (*In dept study: Sorting*). To facilitate the new procedure it is recommended to combine the same colour rather than the same décor design when planning the layout of the plates.

Remedial strategies / Recommendations

Clear colour coding, for example marking statuses with a colour and not just text, would improve the interface of P2 and make order selection easier. Another possible improvement is to only provide relevant statuses when changing the status. The pop-ups when someone else is working within P2 should also be investigated further. The major reason for this is that normally operators are not working with the same order simultaneously and therefore it should not matter if the system would remain unlocked when other statuses are changed. With increased programming, the middle step where the

décor files are first downloaded *Backstage* and ripped to be used in *Merge* could be eliminated and hence save time. It would also reduce the risk of choosing the wrong version of décor-files. More solutions as to planning the plate layout in an optimal way are presented in appendix 3 (*In depth study: Sorting*).

2. Imager combi

In the imager, the previously planned décor layout is used to treat the black layer of the plate with laser beams. Directly after a section is imaged with the laser it is also exposed with light (main exposing). When the plate is both imaged and main exposed it is transported inside the machine onto a flat surface where it is back exposed. When this is done the plate comes out and may be retrieved, see figure 2.2.

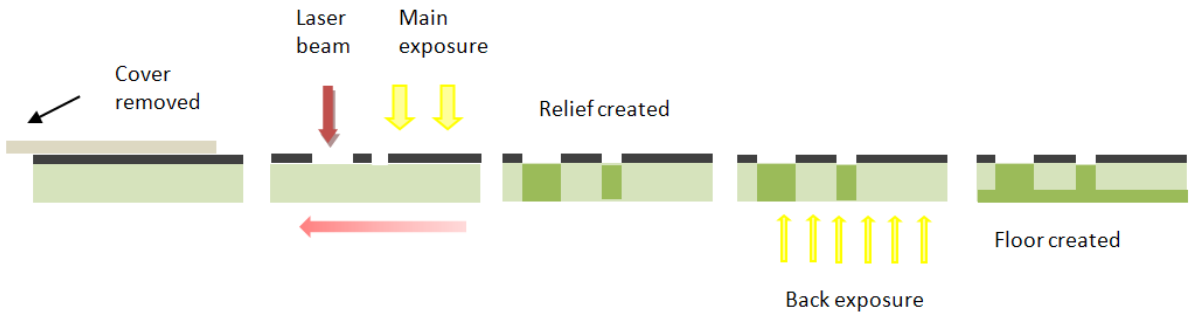


Figure 2.2 Illustration of the functionalities in the Imager combi

Task

The operator first removes the plastic cover and places the plate on a large flat surface on top of the machine. The edge of the plate is then adjusted to be aligned straight and close to the machine opening. The machine settings, e.g. choosing which plate is being imaged, are entered on an attached computer. The operator then pushes the *Load Plate* button on the machine and the plate is automatically loaded into the machine. When the machine has completed all procedures, a plate tray with the plate comes out. If the same procedure as today should be followed, the plate is then lifted by holding two corners diagonally to prevent the surface from becoming scratched and damaged from surrounding objects.

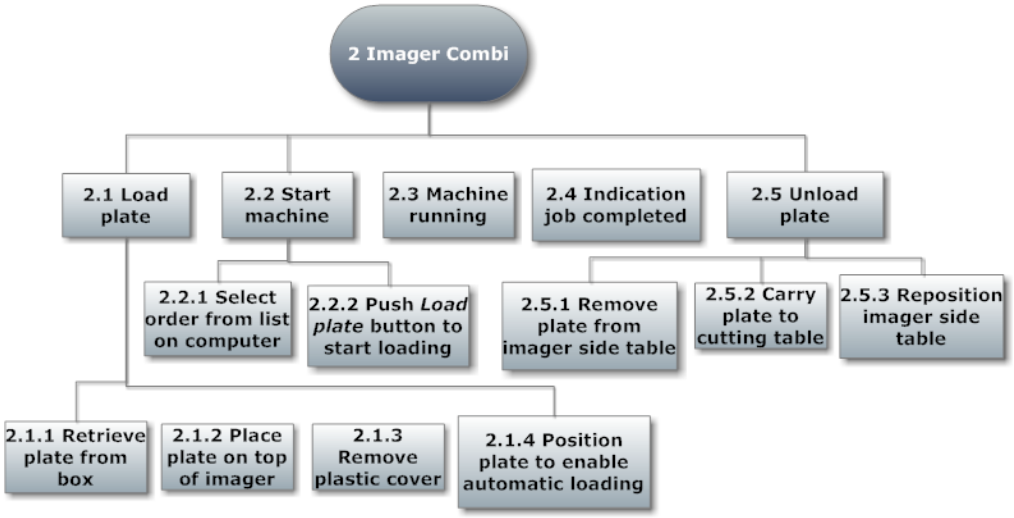


Figure 2.3 Hierarchical task analysis of Imager combi in Easy ITS

Issues

Just as for the Imager used in Lund the Imager combi machine is quite high and therefore the task of loading might be uncomfortable for some of the operators. Today handles are placed on the on top of the machine, close to the front, which increase the loading height further. On the other hand with the new machine the operator only places the plate on top of the machine and does not have to fasten it manually. When the machine is done the plate can be retrieved from a plate tray on an appropriate height. Plate handling is still an issue in this task since they are heavy and difficult to handle, the unloading height is however better than the loading height.

Since the plate has also been main exposed in the Imager combi, the probability of destroying the décor by touching the plate when removing it from the plate tray, is decreased. The step of having to push a button to reposition the laser before imaging each new plate is now programmed into the machine functionality, and hence should no longer be an issue.

Remedial strategies / Recommendations

To facilitate plate handling when loading the plates, especially for short operators, a movable footstool should be provided. The footstool used in Pre-press Lund works well and is appreciated and since the same operator is handling the Imager for the majority of the shift, placing the footstool is worth the effort.

The supplier of the machine suggests that the plate is loaded from the back. A solution built on that assumption could be to automatically load by use of for example a suction grip. It is however required that the space behind the machine is adequate and accessible for this to be possible. If plates are loaded from the front it would be preferable to move the handles a bit further down the front side and/or decrease their height.

Furthermore, a sliding solution between the Imager combi and the Cutting table should be further investigated. This solution should be easier to implement for Easy ITS since the plate tray has a lower height more similar to the height of the cutting table.

3. Cutting machine

The cutting machine automatically cuts along the décor edges imaged on the plate, see figure 2.4. A similar cutting machine to the one used today is used in Easy ITS.

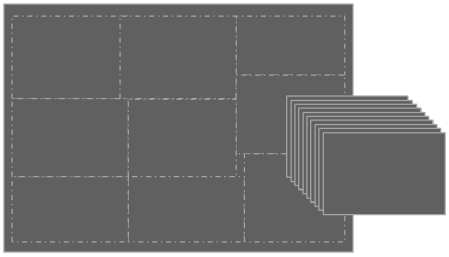


Figure 2.4 Illustraion of cutting pattern in an automatic cutting machine

Task

The operator retrieves the plate from the Imager combi tray and places it on the cutting table. The operator then needs to adjust the cutter head by visually making sure that a cross on either side of the plate is detected and centred. The file representing the plate layout is chosen from a list on a computer and the operator then starts the automatic cutting machine which cuts out each cliché from the pattern of the selected layout file. After cutting, the waste material is disposed.

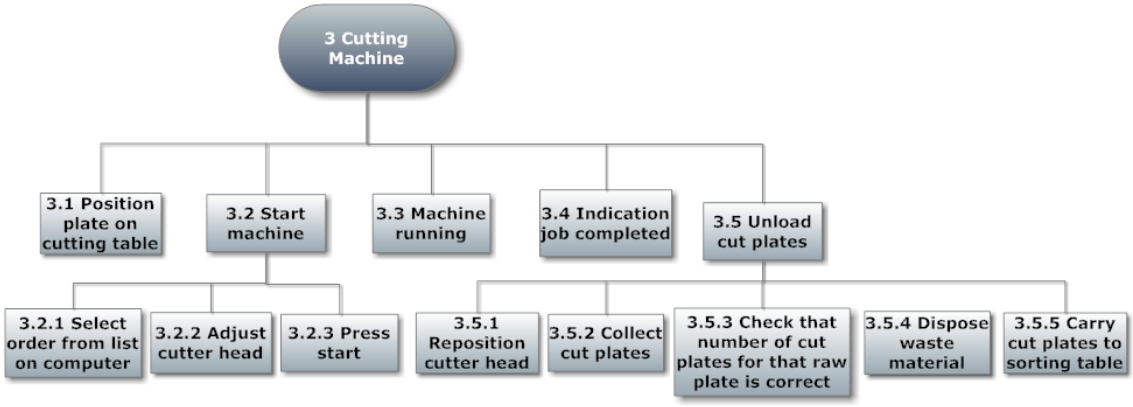


Figure 2.49 Hierarchical task analysis of cutting machine in Easy ITS

Issues

The steps rated as critical here are placing the plate on the cutting table and positioning the cutter head. Placing the plate requires that the operators reach across the table while lifting their arms above their shoulders when holding the plate. This can cause discomfort in back, neck and shoulders, see *Theoretical Framework* (D:8) for examples on appropriate working postures. Additional ergonomic issues in this task are related to standing still for long periods of time.

The task of positioning the cutter head needs to be highlighted since, as mentioned above, the plates are cut before they are processed. This also means that they are still black which influences the visibility of the décor in this stage. Therefore it is important to make sure that the visibility of the cross on the plate is not decreased to the extent that it increases the risk for errors. The cutter head also needs to be repositioned before the cut plates can be picked up which is perceived as time consuming and irritating.

In existing Pre-press, the cutting and sorting tasks are done by one operator in each shift. During interviews the operators expressed that the task is repetitive and demand a high mental focus. Furthermore this task tended to have a high time-pressure to meet the productivity goals. This is important to consider when planning the operators' work distribution.

To facilitate sorting it has been proposed to include a pen function in the ACT to mark each cliché after they are cut. An attempt to do this has been done in Pre-press Lund but complaints were then made on the inaccuracy and inefficiency of the procedure and thus it is no longer in use.

Remedial strategies / Recommendations

As done today, in both Lund and Limburg, rubber carpets should be placed in front of the cutting machines to ease the negative effects from standing, in back and shoulders; however a varied posture is even more important. Since the Easy ITS process is implemented from the beginning there is still a possibility to plan the operator task distribution so that there is a mixture of standing, sitting and moving. Additionally rotations within the shifts should be encouraged.

For positioning the cutter head the black layer on the clichés actually improves the visibility of the cross marks used to position the cutter head as long as the cutting machine-surface is bright and gives a contrast for the cross pattern. Furthermore, the task of needing to manually reposition the cutter head after cutting serves no purpose and it should therefore be possible to include this action when turning off the machine.

4. Sorting

One major difference with the new process is that sorting of the clichés is only done once. Since the mounting process will become automated it is even more important that the sorting is done correctly from the beginning. The operator organises the clichés in order and places them together with the manufacturing report in a pile on a shelf.

The sorting task, as a whole, has been given a high criticality and is considered to be one of the most challenging tasks for the operators in the new process. Therefore sorting is discussed further in appendix 3 (*In depth study: Sorting*) where a recommended working procedure is suggested along with a list of necessary equipment.

Task

The sorting task in Easy ITS is a combination of the sorting done in the Cliché Making and Mounting Preparations. If the order is a single print the lane placement of the cliché on each sleeve does not matter and the clichés only need to be sorted according to colour, i.e. all clichés belonging to one sleeve are placed together (note that one sleeve represents one colour). However, if the lane and date

numbers are already added to the décor design, it is necessary to sort the clichés of the technical colour even if it is a single print. If the order is a co-print the cliché order has to be considered for each lane on each sleeve.

The suggested approach is to sort the clichés in order within each colour and then separate the piles with post-its, see figure 2.6. Information on the post-its could include for example P-order and colour number. The sorting order should be based on the manufacturing report where all necessary information is provided.

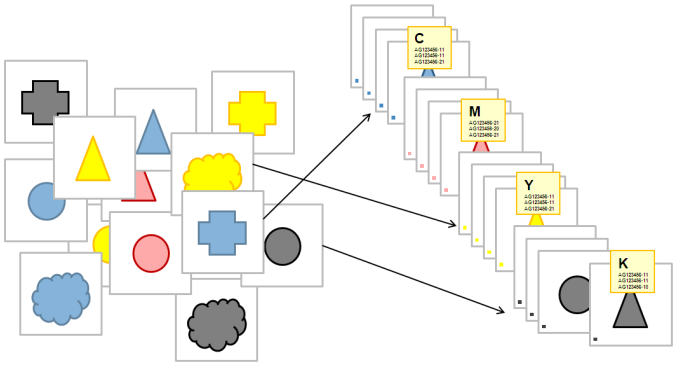


Figure 2.6 Illustration of suggested sorting procedure in Easy ITS

Another suggestion is to incorporate the slitting line, on the cliché in lane one, on the technical colour sleeve for each order, instead of a thin line mounted separately. Blank plates including the positioning mark for printing sometimes needs to be added to the pile as well. The manufacturing report is filled out and signed before the status is changed in P2 and the pile stored. The recommendation is to store it in a rotating shelf as is done in Pre-press Lund.

For a deeper description of these tasks see appendix 3 (*In depth study: Sorting*).

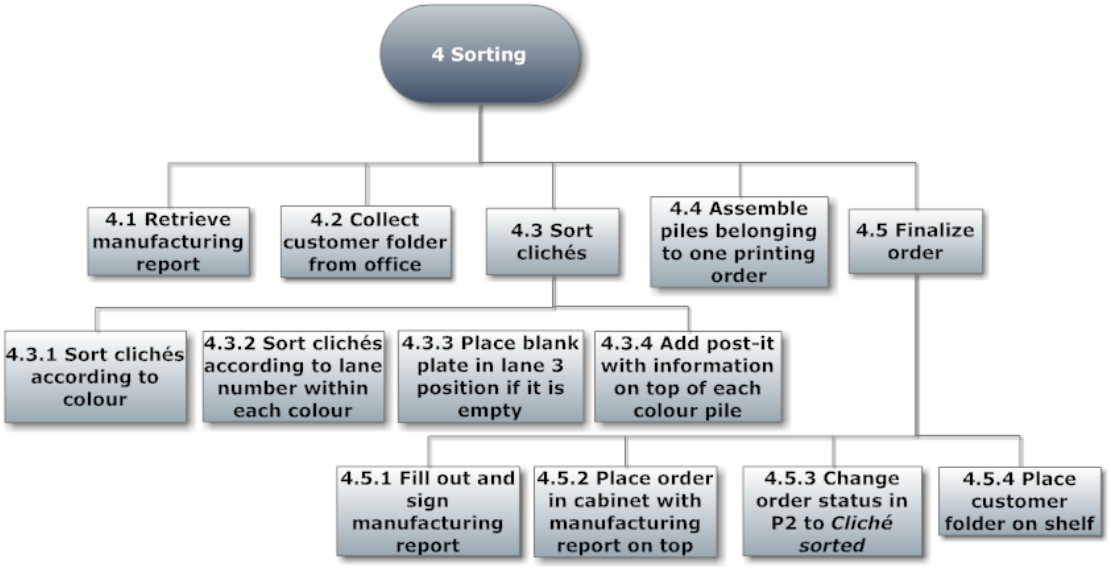


Figure 2.50 Hierarchical task analysis of Sorting in Easy ITS

Issues

The sorting procedure has many critical tasks where the sorting can be done incorrectly. Since the sorting is only done once in the new process the accuracy of these tasks become more important due to fewer checks. As previously mentioned sorting involves standing for long periods of time and also requires a constant high focus. The focus needed for both sorting correctly and managing to see the small numbers on each cliché to place in the correct pile according to information in a manufacturing report, also with small numbers, makes this a critical task.

The stickiness of the clichés makes an appropriate working height important, this since force and high elbows are needed to separate each cliché. Also, if an incorrect status is set in P2 after the pile of clichés is stored there is a risk that the clichés are “lost” within the system and thus needs to be reproduced.

Remedial strategies / Recommendations

To facilitate the use of the manufacturing report when sorting, only crucial information should be included and it should be presented in a clear and structured way, e.g. using colours (as in Limburg). The initial solution to improve the visibility when sorting was to use the pen function incorporated in the cutting machine. It should however be mentioned that the black layer on the plate partly improves visibility of the plate numbers, if placed on a bright surface. To increase the contrast of the numbers a light table is suggested for sorting.

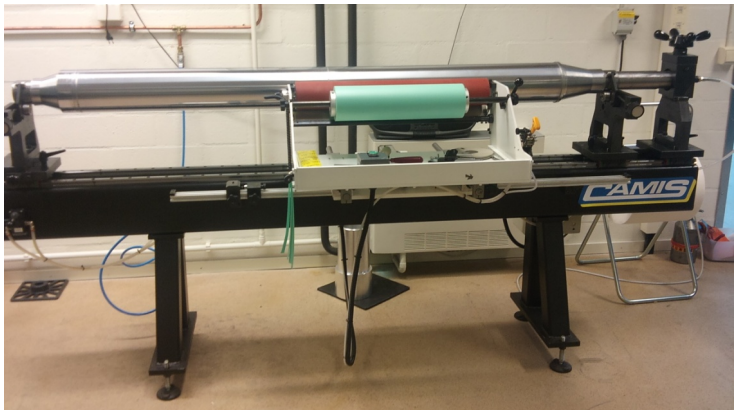
The possibility to do height adjustments, both for different individuals but also for different working positions, for example both sitting and standing, should be provided. The working height affects both the force spectra the operator has to work with, the work posture they can adopt and their sight. Consequently both a height adjustable working table and a height adjustable light table should be provided. The light table is more important to include in the new process because it can facilitate the work with the darker clichés more than it would in the production today.

Since the Easy ITS is implemented from the beginning there is still a possibility to plan the operator task distribution so that there is a mixture of standing, sitting and moving. Additionally rotations within the shifts, during a day's shift, should be encouraged.

More solutions as to sorting clichés before mounting are discussed in appendix 3 (*In depth study: Sorting*).

5. Tape mounting

The Easy ITS process will use a semi automatic tape machine, see picture 2.1, to mount tape onto the sleeves before they can be placed in the Mounting machine.



Picture 2.1 The Easy ITS Tape Mounting Machine

Task

The operator starts by finding out for which order taped sleeves are needed next. Then sleeves are retrieved from the sleeve storage and transported to the tape mounting machine where they are mounted, one sleeve at a time.

Before the sleeve can be mounted the shaft needs to be lifted, which is done by rotating a lever on the side. Air compression is used when pushing the sleeve onto the shaft and the shaft is lowered again by winding down the lever.

Once the sleeve is fixed, a sleigh with a box with an attached roller and roll of tape can be moved along the sleeve, see picture 2.1. The first tape edge is attached using a guiding ruler and the tape is then attached by rotating the sleeve one lap while applying pressure. The tape is then cut along the ruler, overlap tape is removed and the edges are attached with a roller. Then the sleigh with the box is repositioned to mount the next lane. When completed the sleeve is demounted from the machine and placed on a vertical trolley.

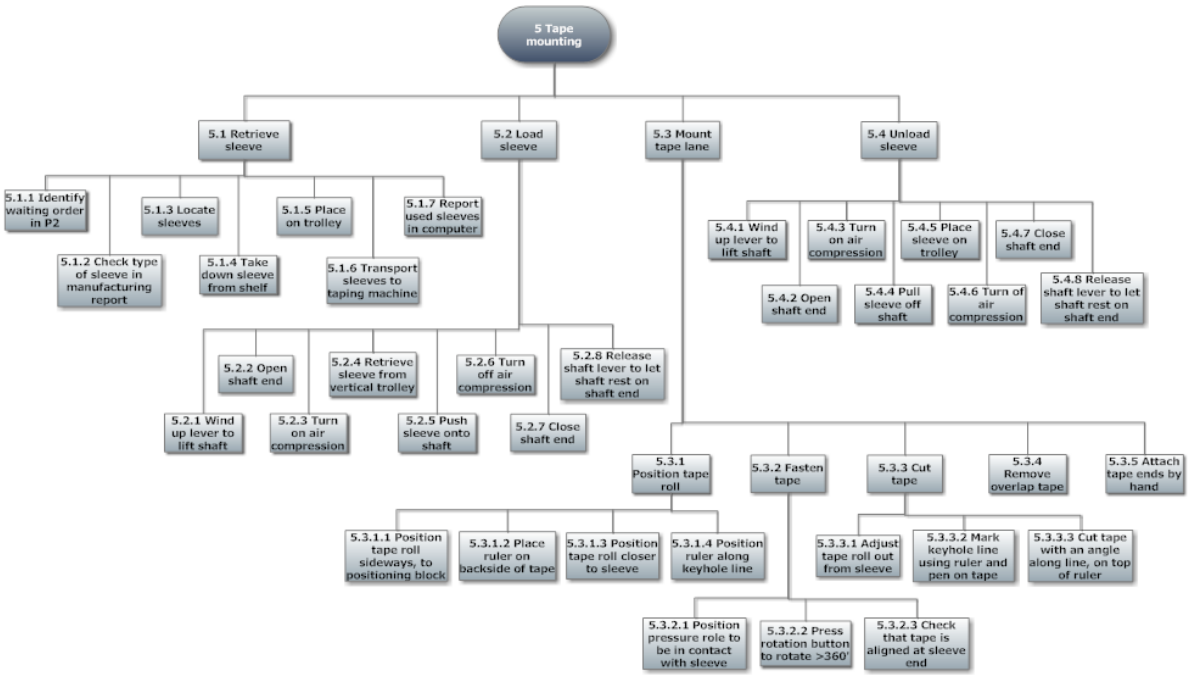


Figure 2.8 Hierarchical task analysis of tape mounting in Easy ITS

Issues

A large amount of critical issues were identified in relation to this task. Initially it is unclear how the communication will work about what orders should be taped and when. This is important to discuss and clearly define, especially since the time pressure for mounting will be altered if the cut plates cannot be stored as long as in existing Pre-press, and because of the shortage of available sleeves.

Furthermore the sleeve storage used in Lund today is, as mentioned before, in no way acceptable. Retrieving the sleeves from storage and transporting them to the taping machine includes a lot of heavy manual handling. The sleeve storage in Lund is very high and sleeves far up have to be retrieved using a ladder. Loading the sleeves onto the trolley also has ergonomic implications since the low shafts are placed too low and the higher shafts too high. Manual handling is further discussed in appendix 4 (*In depth study: Manual handling*).

Another issue is that sometimes the needed sleeve types are in use and hence not available for production. This is a latent issue that happens when many prepared orders in a row require the same sleeve type. When transporting the sleeves to the mounting area there is a risk that the operator either runs into someone else, runs over his or her own foot with the trolley or collides with an automatic carrier.

The lever used to wind up the heavy shaft is very short and a lot of force is needed. Air compression minimises the force needed for pushing the sleeve onto the large shaft but if one attempts to pull off or push on the sleeve before the air compression has worked up full pressure, there is a risk for injuries if the sleeve suddenly moves more easily.

Picture 2.2 Operator using the tape machine

The box with the tape roll forces leaning and high arms to place the tape edge, which creates an awkward posture, see picture 2.2 above. Also the roller included in the machine eliminates most air bubbles under the tape but it also, together with the diameter of the tape roll, forces high elbows when attaching the tape. Difficulties in placing the tape edge correctly are also rated as critical due to the high frequency of the errors in observations. The tool for positioning the tape roll sideways also needs improvement since it is tedious to reset it for each lane. Nor is there a good tool for redoing a lane of tape and rolling it onto the roll again.

Remedial strategies / Recommendations

It will be necessary to find a solution about how to communicate what order to tape and when the sleeves need to be ready for mounting, especially if the time pressure for mounting is be altered if the cut plates cannot be stored as long as before. To avoid that sleeves required are not available, communication between the operators is crucial.

To place a rotating shelf system close to the taping machine, within the Pre-press area that delivers the sleeves on an appropriate height is the primary suggestion. Furthermore the choice of trolleys could also reduce the impact of sleeve handling and the sleeve shelf and mounting area should not be separated by an automatic carrier path. Additional recommendations and remedial strategies to minimise and improve manual handling are discussed in appendix 4 (*In depth study: Manual handling*).

There is a range of improvements that could be done to the tape machine design. Initially, the shaft lifting lever should be made automatic, using a motor. The positioning of the sleigh including the tape and the tape roller could be pre-set sideways suitable for each tape width as done in the Microflex today. Furthermore the box with the tape roll should be decreased, its large size has no apparent functionality and it could easily be decreased to allow the operator to stand closer to the sleeve.

Another recommendation is to investigate the possibility to use a Microflex machine which is used in Pre-press Lund for Tape mounting which both eliminates air bubbles and facilitates positioning of the tape edge. The Microflex has been improved by several WCM teams to make it as ergonomic as possible and the operators are already accustomed to this equipment.

6. Plate mounting

Plate mounting involves loading the machine with the correct sleeves that match the pile of clichés placed in the machine. The machine then mounts the clichés, one at a time, onto the taped sleeves.

Task

The operator starts by finding out which order should be mounted next, this is done by checking P2 for the waiting order with the correct status. Sleeves are then retrieved, assuming they are available and taped, and if not, another order must be selected. The sleeves are retrieved with a vertical trolley and then placed on the horizontal trolley, specially made for the mounting machine. After a plastic tape cover is removed from each sleeve the trolley is positioned inside the machine.

The operator then needs to identify and select the correct pile of clichés for the order. A check should be done to make sure no mistakes have been made in sorting, the pile is then placed in the cliché trolley where toggles are adjusted to secure the placement of that format of clichés. The cliché trolley is then positioned inside the machine. Before the machine is started settings defining format, type of sleeve, number of lanes and any deviations from a normal mounting setting, need to be entered.

The hierarchical task analysis below, see figure 2.9, describes the tasks involved in plate mounting. All task analyses can be found in written form in appendix 5.

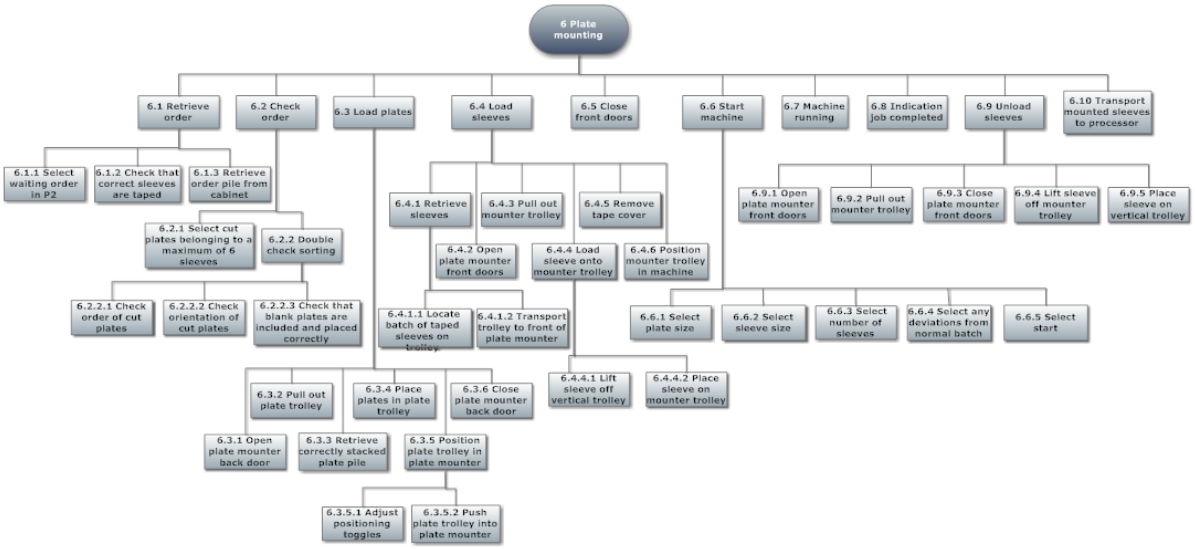


Figure 2.9 Hierarchical task analysis of Plate mounting in Easy ITS

Issues

Manual handling of sleeves has been given a critical status in this task as well, much due to the fact that vertical trolleys are used and each sleeve is handled several times, both when loading and unloading the machine. Many of the issues related to this are common for all sleeve handling and are discussed in appendix 4 (*In depth study: Manual handling*) so will therefore not be discussed further here.

When adding settings to the machine there is a risk of not reporting, or reporting incorrect, deviations in the mounting plan which will affect the mounting of each following cliché in the pile. Positioning the

toggles in the mounting machine is perceived as slightly difficult and more complicated than should be necessary, as they are fastened by screwing them into place.

As discussed previously the number of sorting tasks is reduced to one and the only chance to make sure sorting has been done correctly, or notice inaccuracies, is in this task before they are placed in the mounting machine. The consequence of an error slipping through this task has critical consequences.

An unclear issue is the time limitations of storing a cliché before it is mounted and processed. This needs to be further investigated. Also, required sleeves for an order may not always be available and taped which needs to be taken into account when planning the production.

Remedial strategies / Recommendations

To make sure the correct clichés are mounted and that the corresponding settings and deviations are entered, a proper information communication system is crucial. Barcodes containing information or illustrations of deviation settings are some suggestions to minimise mistakes. Furthermore the operator loading the clichés should perform a quick check to make sure the clichés are the right ones and in the right order. To facilitate cliché positioning in the cliché box the positioning toggles could be kept in place by a spring that is pulled out when they need to be moved.

Communication is very important to avoid starting to load an order for which there are no taped sleeves. This type of planning should be included when selecting the order to be mounted next.

7. Processor

The new processor incorporates three main functions, it removes the unhardened polymers by use of solvent and brushes and the mounted clichés are then also dried and light finished.

Task

The operator retrieves one sleeve at a time from a vertical trolley and positions it in the processor by placing it horizontally on two sleeve rests after opening the processor door. When mounted, the new sleeve is entered in the processor system and goes through the three process stages. When a sleeve is finished the operator opens the processor back door, picks up the sleeve from the sleeve rest and places it on a trolley.

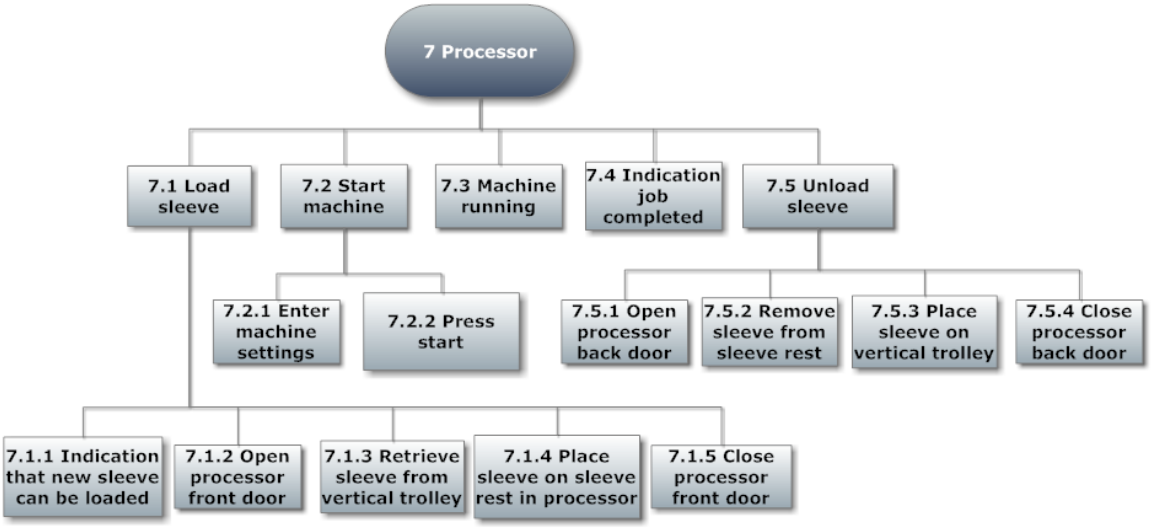


Figure 51 Hierarchical task analysis of Processing in Easy ITS

Issues

From discussions with ergonomist Ulrika Welin, the height of the sleeve rests onto which the sleeves are placed should be considered. The loading rest was a bit too high and the low door may force a tall operator to lean back while placing the sleeve. The rest from which the sleeve is unloaded was according to Ulrika Welin slightly low.

In addition to being placed high, the front door requires a lot of force to pull down and close. The back door has similar features but is placed lower and thus slightly easier to handle.

Lifting the sleeves from a vertical position (from vertical trolley or the floor) to a horizontal one, is not ergonomically preferable since a lot of twisting movements are involved. Manual handling of sleeves have been given a critical status in this task, much due to the fact that vertical trolleys are used and each sleeve is handled several times to load and unload the machine.

The solvent used in this processor is still a strong chemical which the operator will be in less contact with now than in the previous process. However for cleaning and maintenance the machine needs to be opened and a strong smell may be an issue.

Another discussion is about the choice of indication that a sleeve can be loaded and unloaded. A solution was developed to make it possible to load a new sleeve as soon as the previous was removed from the sleeve rest. This sleeve will then be automatically picked up by the machine when the parameters have reached a required level and the previous sleeve has been moved from the first stage to the second. This solution in a big way eliminates the use for clear indication on when a sleeve can be loaded.

The choice of indication on when a sleeve needs to be unloaded is still open for discussion. The current solution is a field that changes colour on the display but this is not visible from the side the sleeve is unloaded from.

Remedial strategies / Recommendations

To minimise issues with the processor doors they could be opened automatically by use of a button or a pedal, making it possible to open while holding a sleeve.

To minimise implications due to manual handling, the main goal should be to avoid the use of vertical sleeve trolleys in this task as well. Another solution under discussion within the development team in collaboration with the supplier is to incorporate the mounting trolley in the processor where the sleeves are automatically picked up one by one and loaded into the machine. If possible this would be a very good solution eliminating a large part of the critical sleeve handling.

In order to maximise efficiency in the use of the processor a clear indication from the processor when a new sleeve can be loaded is suggested. A general impression is that light is preferred over sound. For light indicators such as a blinking lamp it is important that the lamp is visual from most parts of the room where the operator usually is. An optimised layout helps to improve this visualisation and also the possibility to see through the machine that the sleeve is finished.

The solution that a sleeve may be loaded as soon as the sleeve rests are vacant, and then automatically started as soon as possible, secures maximum efficiency. For unloading a clearer indication should be considered. Colour coding would be beneficial and could be done by for example using a larger coloured area in the display or lamps in different colours, e.g. green for *ready to unload*, yellow for *processing* and red indicating *something is wrong*.

8. Finalise order

In this step the full batch is gathered and if requested some or all sleeves will be checked in the quality control unit before they are approved and sent to printing. Also, the paper work is filled out and stored for future use.

Task

In this step the manufacturing report is placed in a folder that will remain in the Pre-press department, making it possible to trace issues identified later in production. Since information also needs to be delivered to Printing, a new delivery report is retrieved with a checklist that is filled out and then the report is signed.

If a request for a quality check is given, the operator needs to perform a number of quality checks which is done in quality control machine onto which the sleeve needs to be positioned onto a shaft similar to that of the tape machine. Except for loading, unloading and manual checks, this task is not part of the Master Thesis scope but should be taken into account when distributing and planning operator tasks. Finally the order status in P2 is changed to *Ready to start*. The sleeves for the order are now ready to be transported to Printing.

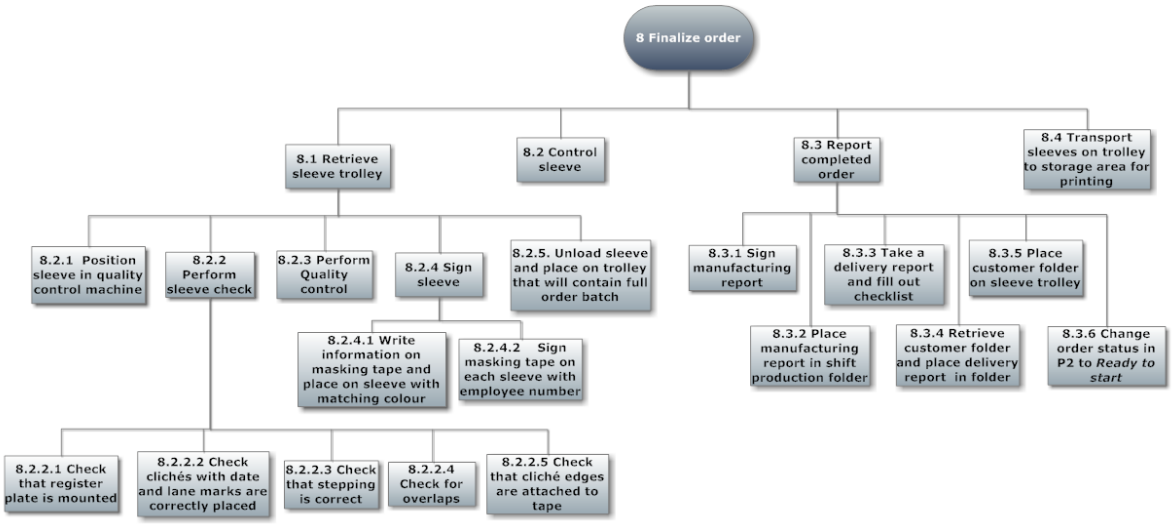


Figure 2.11 Hierarchical task analysis of Finalise order in Easy ITS

Issues

The handling of sleeves, as usual, includes ergonomic issues. Also the transportation of the sleeves to Printing may include risks connected to crossing automatic carrier paths or colliding with other objects.

The only other critical issue identified in this task is the risk of changing to the wrong status in P2. If this is done there is a risk that the order is delayed because the information about the ready order is not sent to Printing.

Remedial strategies / Recommendations

It is recommended to plan that sleeve transport in a way that avoid crossing automatic carrier ways, since this would otherwise create a number of risks. Once again, the choice of trolleys to use is discussed further in appendix 4(*In depth study: Manual handling*).

As suggested before, the manufacturing report or delivery report could be connected to P2 in the way that the information entered on the report on paper could be entered into the computer program instead. This would minimise the amount of paperwork and would function as a barrier to make sure that all necessary information has been entered before the order is sent to Printing. In different process steps P2 could for example require certain information to be able to change status. This solution should however be discussed further with the operators because having the information on a paper is sometimes preferred. An easier solution is that the forms handled today are looked through and all unnecessary information removed.

In Lund the delivery report travels to printing in a pocket on the sleeve trolley. It is therefore important to include this feature on the trolleys that will be used in the Easy ITS as well.

Appendix 3
In depth study: Sorting

This chapter will be initiated with a description of how sorting and handling of clichés is done in Pre-press today. Issues with the existing system are identified followed by recommendations and proposals for how sorting could be done and improved in the Easy ITS process.

1. Sorting in Existing Pre-press, Lund

Most of the information in this part of the project was gathered through visits to Pre-press Lund and interviews with operators and customer archive planner. For additional clarifications official instructions were studied.

1.1. Overview

In order to perform a more in depth study on how clichés are handled and sorted along the Pre-press production line, the task steps of how it is done in Lund were investigated further. To do this, the task analysis describing the whole Pre-press process was updated to be more accurate and to include a larger scope of the steps of sorting clichés. A new version of task analysis was then put together to include only the tasks that are related to sorting and handling information along the process. This task analysis can be found in the end of this appendix.

Several actors affect the process of sorting and handling of clichés along the production line to make sure that the décors end up on the correct print. These process steps have to be coordinated for an effective and correct process.

Table 3.2 Actors involved in sorting and handling clichés

Actors	
Customer Sales Representatives (CSR)	Gather all orders worldwide and distribute them to Tetra Pak factories.
Production planning Lund	Responsible for all orders coming to Lund and for ordering material.
Customer folder archive (CFA)	Archives and prepares customer folders containing reference printouts and prepares production orders for mounting.
Digital files preparations	In charge of supply and updates of digital design-files and reference print outs.
Cliché	Plans plate layouts and creates cuts and sorts clichés.
Mounting	Sort clichés further, prepares sleeves and finally mounts clichés.

To organise the information about the working steps in this part of the report the steps including tasks connected to sorting have been divided into the following groups; Order preparations, Cliché Making, Mounting preparations and Cliché Mounting.

Table 3.3 Overview of tasks involving sorting and handling of clichés

Tasks	
Order preparations	Customer sales representatives Production planning Customer folder archive Digital files preparation
Cliché Making	Customer sales representatives Production planning Customer folder archive Digital files preparation Plan plate layout Sort cut plates
Mounting preparations	Retrieve cliché order Sort cliché order
Mounting	Retrieve and control order

1.2. Information flow that affect sorting

To complement the task analysis some parts of the process are further explained below. To manage the information flow through the process different reports and forms are used. Here the information about the order such as the décor order, machines used throughout the process and checks done are noted.

Naming the plate

When the plate layout has been planned, a file containing the layout information is sent to the Imager and the Cutting table. The file is named by the operator and this file name is then what is selected in lists in the later processing steps. The name is also printed close to the right corner of the plate. Today there is no standardised recommendation on how to name the plates, instead the operators have different routines and expressed that they do not feel a need for a standard.

Production order

Each design has its own production order which is printed out by the customer folder archive manager. The production order contain a lot of information that will be used in later processing steps, such as colour specifications and a barcode specifying if holes for straws should be punched. Today the barcodes are added in another computer program, which adds an extra task for the archive manager. Furthermore information about the décor lane placement is defined here. In the example below the order is a co-print with six lanes with different décors in each lane.

Since a few years back the lane-distribution of the differing designs in co-prints is planned already when the orders are put together by CSR (Customer Sales Representatives). This means that the knowledge of how to distribute pressure evenly along the sleeve is not needed by the operator in cliché. Information about which design/cliché should be put in what lane on the sleeve is given on both the production order and the manufacturing report.

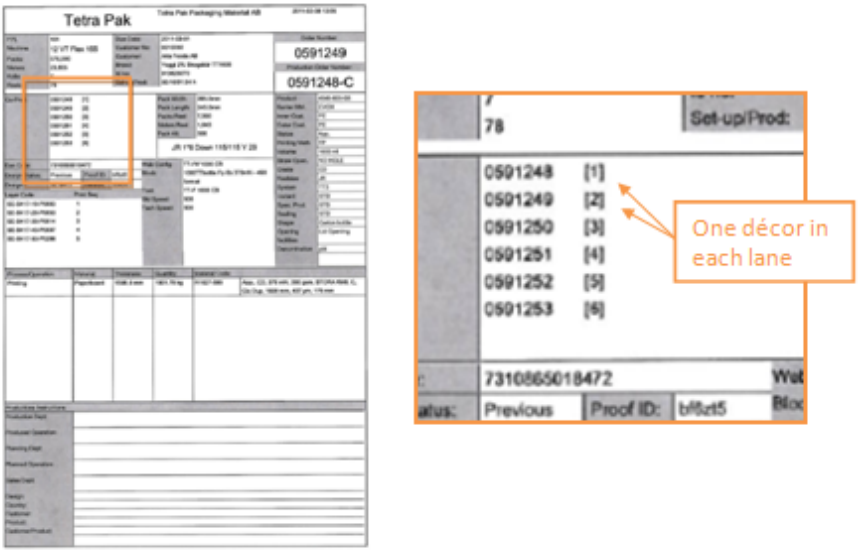


Figure 3.1 Production order

Manufacturing report

In the Cliché Making department the manufacturing report is printed. This form includes the whole printing order on one piece of paper, i.e. all designs if co-print. The front side of the manufacturing report is used mainly by Cliché Making and the backside by Cliché Mounting.

Four different operators use each report, one planning and creating the plate; one cutting, drying and sorting the order in Cliché Making; one sorting according to lanes and colour in Mounting Preparations and finally the person mounting the clichés in Cliché Mounting. All these operators must sign it with their employee number after finishing their task. Below follows an illustration and clarification on what is included on the manufacturing report (figure 3.2 and 3.3).

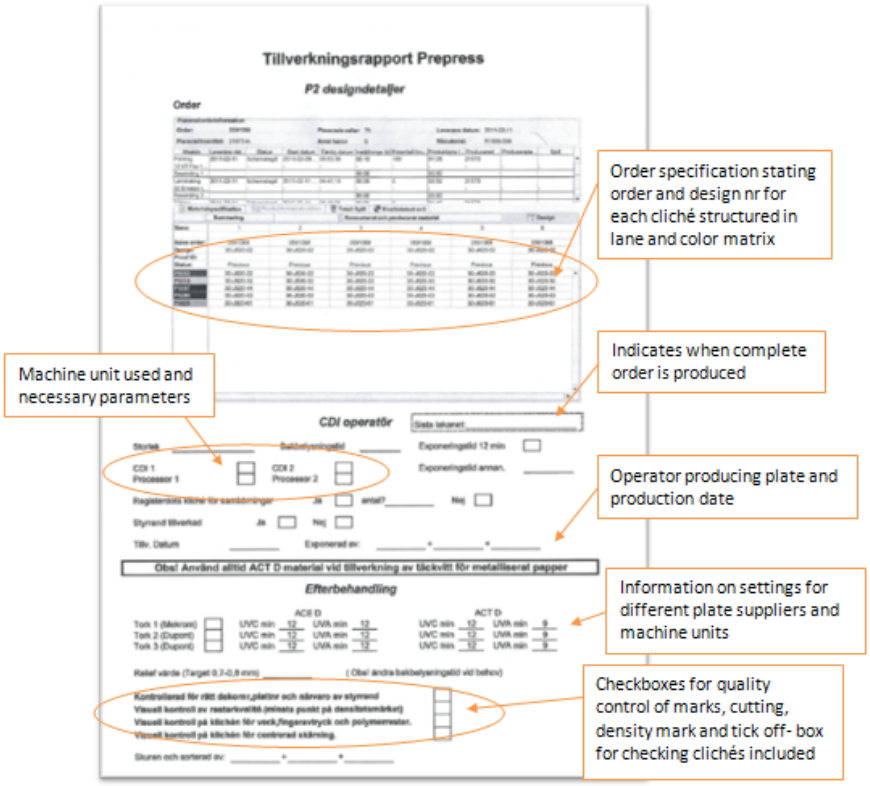


Figure 3.2 Manufacturing order with explanations, page 1

The handwritten checklist, for lane and colour layout, on the back of the manufacturing order (figure 3.3) is a clear issue in the existing Pre-press line. It serves no obvious purpose but has been kept since previous procedures. All the information needed is provided on the front side of the manufacturing order (see figure 3.2 above). Horizontally each colour/sleeve can be read and vertically each design/lane is grouped. For each cliché the complete décor number is also stated which may be compared to the code on each cliché.

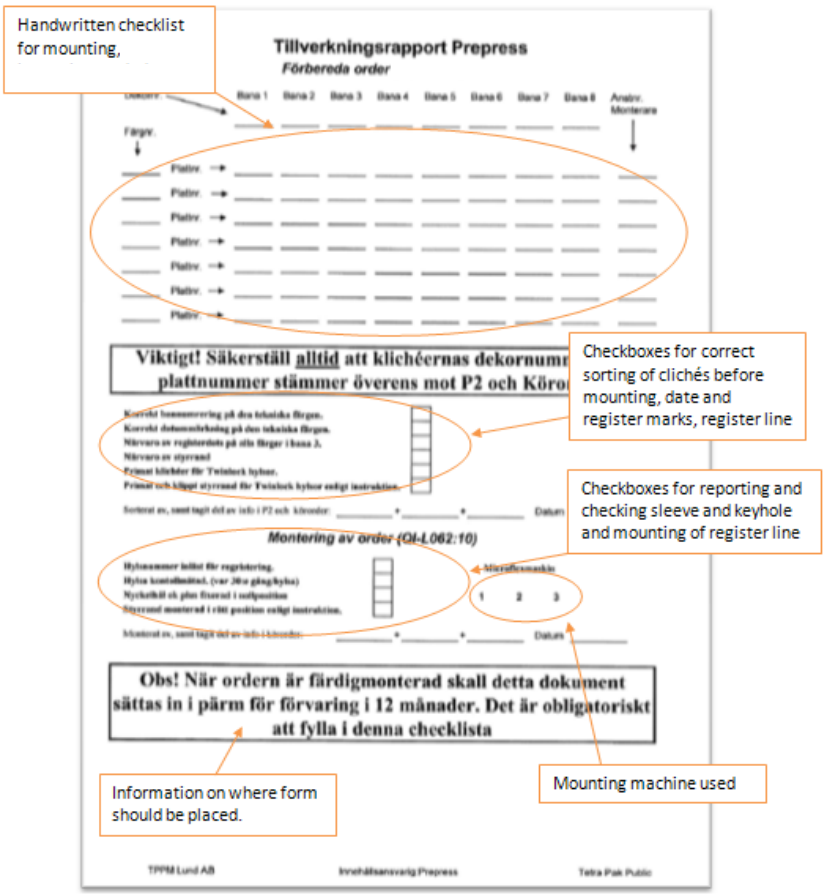


Figure 3.3 Manufacturing order with explanations, page 2

Lane and date marks

If something incorrect is detected in Printing or even later when it arrives to the customer, it is important to be able to follow up and find out what has caused the defect. One way to follow up is to include date and lane number on each print. The existing way of doing this is by using circles including month, year and lane number on each décor. On the clichés belonging to the technical sleeve (i.e. the sleeve with the darkest colour) the specific month, year and lane numbers are cut off.

Identified issues with this:

- Cut off polymer ends up somewhere on the print.
- Possibility for human error, i.e. that the wrong number is cut off or that the step is omitted.

The possibility to include date and lane numbers in the Imager should therefore be investigated. Dates would not affect sorting at all since the same date is added to all lanes. Adding lane numbers already when imaging would however make the order of clichés, of the technical colour, relevant for single-prints as well.

1.3. Sorting procedure, Pre-press Lund and Limburg

In order to clarify the sorting procedure, what needs to be done and how it is done some illustrations are provided below.

Single-print

For single-prints the sorting is performed in Cliché Making, after cutting, and then only double checked and mounted in Mounting Preparations. This task distribution is outlined in table 3.3 and illustrated in figure 3.4.

Table 3.4 Sorting tasks for single-print order, Pre-press Lund

Cliché Making	Within each design (here only one design per order), the clichés are organised according to colour.
Mounting Preparation	The same order of sorted clichés can be kept since this is the order in which they will be mounted onto the sleeves.
Mounting	Double-checking and mounting on sleeve

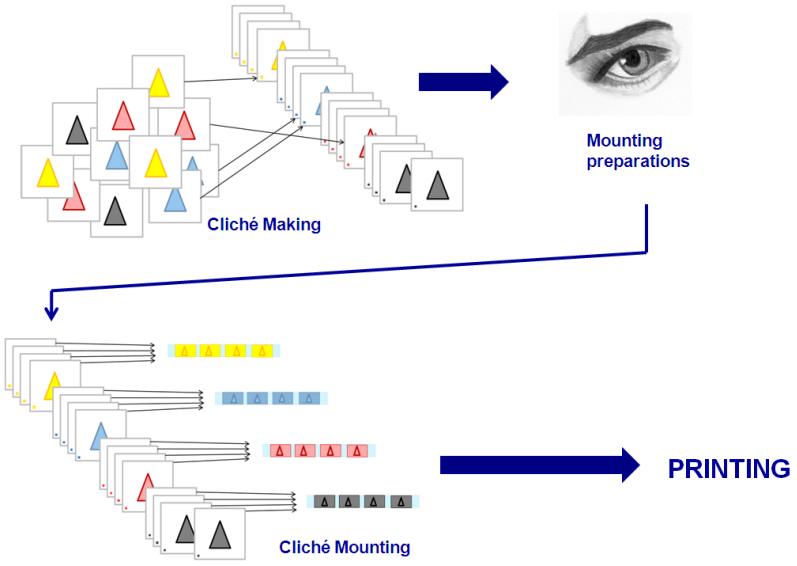


Figure 3.4 Single-print sorting procedure, Pre-press Lund

Co-print

For co-prints there is an additional step, here the clichés have to be re-sorted in Mounting Preparations before being double-checked and mounted in Cliché Mounting. This task distribution is outlined in table 3.4 and illustrated in figure 3.5.

Table 3.5 Sorting tasks for co-print order, Pre-press Lund

Cliché Making	Within each design (here only one design per order), the clichés are organised according to colour.

Mounting preparation	The clichés are organised in colour order by taking one cliché from each design pile and into the order they will be mounted on the sleeves.
Mounting	Double-checking and mounting on sleeve.

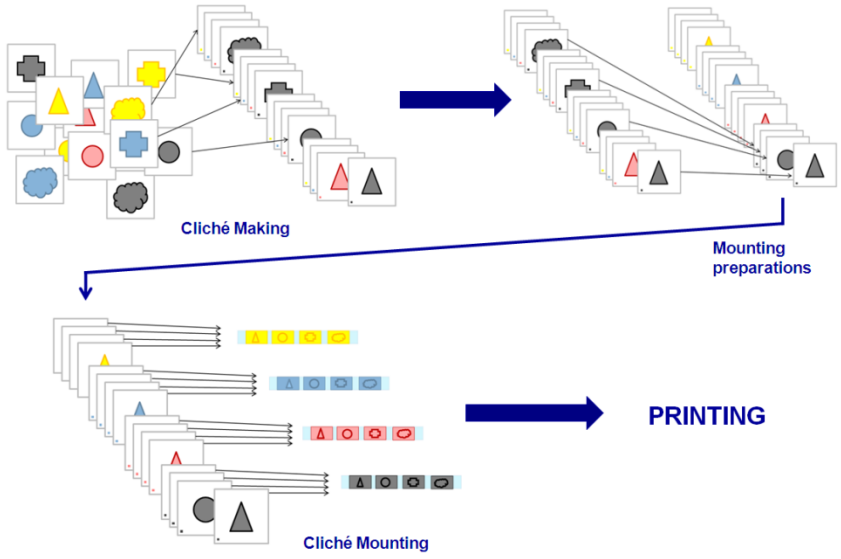


Figure 3.5 Co-print sorting procedure, Pre-press Lund

In Limburg the sorting of co-print orders was facilitated by placing post-its between each sub-pile. The second sorting was done by the Mounting operator.

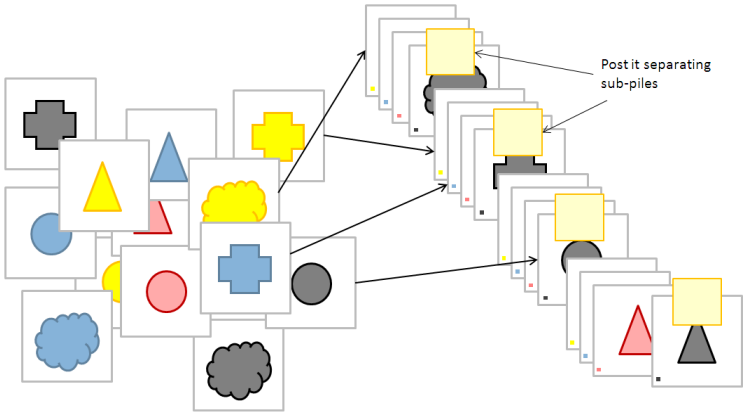


Figure 3.6 Co-print sorting procedure, Pre-press Limburg

1.4. Resources needed

In Cliché Making the order is sorted after cutting. One of the three operators does drying, light finishing, cutting and sorting. Interviews have shown that the time pressure is usually highest on the operators doing these tasks. The time needed for sorting is estimated to 60% of this operator's shift.

In mounting, two operators in each shift do mounting preparations, i.e. retrieving sleeves, sorting clichés and punching tape. For each shift approximately 12 orders should be prepared, regardless of type and size of the orders, which is very rarely a problem. The time used for sorting is here estimated to be 50% of each operator's shift, meaning in total one operator doing nothing but sorting each shift.

This concludes a total of 1,6 operators sorting for the majority of their shift, which is usually 8 hours, producing at least 12 orders (probably more in Cliché Making since they do not produce during weekends). This leads to the estimation of 1,5 operators devoted to sorting each shift.

1.5. Equipment used

Equipment and space needed for sorting and handling clichés is stated below.

Sorting surface

Today the sorting in Cliché Making is done on top of the Light Finisher. This is not an appropriate working height since the operator here has to work far above the recommendation of waist height. In Cliché Mounting the sorting is usually done on the light table. The table is low but the operators have the possibility to sit while working. Additionally some operators have expressed that it would be useful to be able to sort clichés close to other activities that include waiting times, this would allow them to sort while the other machine is running.

Storage

Between Cliché Making and Cliché Mounting the clichés are stored in a rotating shelf mutual for both departments. The shelf is a so called paternosterverk, a type of rotating shelf system where only one shelf is open at a time, meaning an appropriate working height is kept at all times. However, it requires well displayed information on how to find a certain shelf and where certain orders can be found.

2. Sorting Easy ITS

Once a clear image was gathered on how sorting works in the existing Pre-press, a suggestion on how the working steps could be structured in Easy ITS could be provided.

2.1. Overview

Below the actors included in the process are stated and a suggestion on how the responsibilities should be distributed when introducing Easy ITS. One large difference is that Pre-press will no longer be divided in two separate departments as it is today. This will most likely decrease the amount of steps in sorting and handling the clichés.

Actors

Concerning actors, most should maintain the same responsibilities as in Pre-press. Within *Order preparations* all actors will maintain the same tasks while all tasks previously divided between the two departments will now all be distributed under the task group *Cliché Making and Mounting*.

Tasks

Due to the joining of the Cliché Making and Cliché Mounting, the structure of the tasks is also affected. As mentioned, Cliché Making, Mounting Preparations and Cliché Mounting have been joined into *Cliché Making and Mounting* and it is within this group of tasks that changes will be made when introducing Easy ITS.

Table 3.6 Overview of tasks involving sorting and handling of clichés in Easy ITS

Order preparations	Customer sales representatives Production planning Customer folder archive Digital files
Cliché Making and Mounting	Plan plate layout Sorting Plate mounting (preparations) Finalise order

2.2. Information flow affecting sorting

Production order

The production order should still be printed and handled as in existing Pre-press line.

The printing and handling of the production order seem to be working well except for adding of the barcode (including information about punching for printing). The adding of the barcode should be included in the file before arriving to the customer folder archive since this would save a lot of time and avoid a frustrating task.

Manufacturing report

The manufacturing report needs some restructuring to comply with the Easy ITS system. Below follows a list suggesting what should be included in a manufacturing report for the Easy ITS process.

Suggested material on manufacturing report:

- Large order specification stating order and design nr for each cliché structured in lane and colour matrix. If placed horizontally it can be made more visible (see figure 3.7).
- Box for name of last sheet to clarify when an order is completed and may be sorted and placed in storage
- A box for stating which machine unit has been used (which Mounting machine, Processor, etc). Boxes for parameters needed for follow up.
- Date and name of operator performing imaging, sorting, cutting etc. (This could be divided into tasks of several units if this task distribution is set).
- Information on settings for different plate suppliers / Clarify what plate supplier should be used.
- Relief target and space to fill out measurements.
- Checklist for sorting or tick off- boxes for each colour completed etc.

- Checklist for each type of object that should be included in the pile.
- Box to fill out storage location.
- Clarification on who has final responsibility and thereby signs the report.

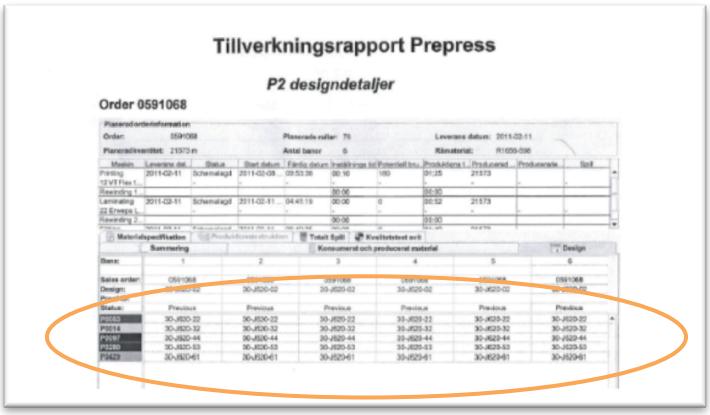


Figure 3.7 Order matrix, manufacturing report

Date and lane marks

Lane and date numbers on the clichés could be included already in the Imager combi. The most reasonable solution would be that the operator, who plans the plate layout, also adds date and lane marks to the selected clichés before the files are sent to the Imager combi. Date marks would not influence sorting at all since they are included in all lanes for the technical colour. Lane marking would however mean that clichés for the technical colour needs to be sorted by lane.

If the date and lane marks are not included already when imaging, the marks need to be cut off after the cliché has been mounted and gone through the processor. The risk of placing the lane numbers incorrectly when sorting is eliminated by this, but the risk for cut off waste on the finished clichés could be a large issue and it will also still be a time-consuming activity. Additionally, errors done here would have a serious consequence since they would both need to be remade and remounted.

Marking

Visibility of décor number on the clichés after cutting is slightly better than before assuming there is enough lighting. A light table would for example make visibility very good. Another way to increase visibility is to mark each cliché with large letters or numbers. (e.g. M1, M2, M3 etc. for the magenta sleeve lane 1, 2 and 3 or 1:1 for sleeve one, lane one etc.)

In the cutting machine there is a possibility to include a pen-function, this function has been used previously but was disliked by several operators because it was time-consuming and not always trustworthy. It should also be said that some operators liked the aid of having information on each cliché in large text and many used their own markers when sorting to make sure no mistakes were made. However, if the pen function is made more reliable and the process less time dependent on one single cutting machine, this could be a very good way to facilitate sorting. To note is that time saved in sorting should be compared to time lost from pen function.

Due to the new process the use of a black marker would not be visible because the black coat of the plate will not be removed until the cliché reaches the processor. One solution for this would be using a silver pen for example, important is however to make sure the thickness of the "ink" from the pen does not affect the print. Since it will be used on the backside of the cliché it will not be removed in the processor. Another suggestion is using a fluorescent pen. This would require special UV lighting and perhaps dimmed general lighting which could in itself negatively affect visibility when sorting.

2.3. Sorting procedure Easy ITS

The sorting procedure starts already when the plate layout is planned. By grouping designs belonging to the same colour of a printing order the sorting is facilitated following steps.

Suggested sorting procedure Easy ITS:

1. When a plate is cut the clichés are brought to the sorting bench directly. Therefore the sorting bench is preferably placed close to the cutting table.
2. When sorting the operator sorts the clichés in sub piles containing all clichés belonging to one sleeve, despite if it is co-print.
3. To separate each sub-pile, post-its are used to make sure all clichés belonging to the same sleeve are picked out. Each post-it can then be marked with information such as order number and design number (see figure 3.8).

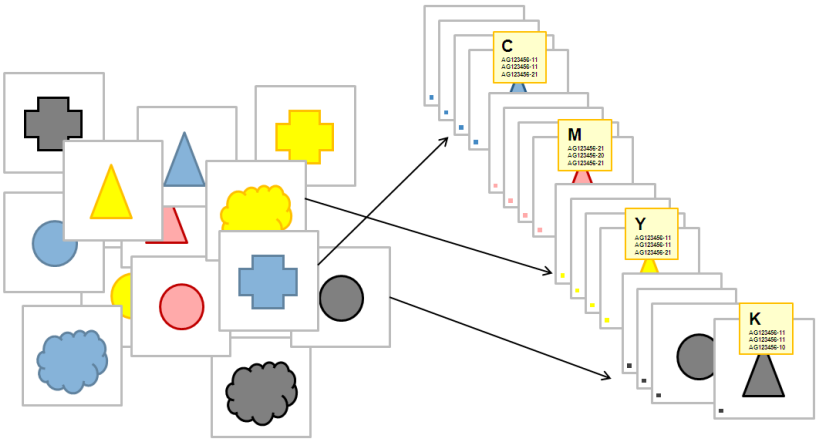


Figure 3.8 Sorting suggestion Easy ITS

Depending on how sorting will be structured it could be facilitated planning plate layout in a way that complies with it. For example, if clichés should be sorted by colour/sleeve after cutting it would be preferable if e.g. all magenta plates are produced together followed by cyan etc. meaning the clichés can be sorted straight away and many different clichés do not need to be sorted simultaneously.

2.4. Resources needed

From the conclusion made from resource requirements for sorting in Pre-press, and applying the same system in Easy ITS, the required resources would be similar. The facilitating procedures and improved conditions make work more efficient but in combination with increased production rates and higher

stress on the accuracy of sorting, the final resource requirement should not change significantly. Therefore the suggested personnel needed for sorting tasks is set to **1-2 operators per shift**.

2.5. Equipment needed

Sorting bench

Due to visibility, the main area for sorting should be a light table. The height of this area should be adjustable to fit different body measurements but should also allow a varied posture for example both sitting and standing. It is of high importance that adjustments are easily done, otherwise it is likely that the feature will not be used. Another alternative is a tilted table which gives a better working posture and better overview of a large table/area.

To plan the plate layout as efficiently as possible, two cliché formats are usually produced simultaneously. It is therefore important that there is room to sort multiple ongoing orders at a time. With the assumption that only two printing orders are sorted simultaneously the surface needed is at least an area of 1.6 m wide and with at depth that corresponds to the length of two clichés of the largest diameter sleeves. Another alternative is a shelf system placed nearby where sub-piles can be placed when they are completed, preferably with a colour and order coding system. This would require less room and avoid leaning over a large table. It would however not give the same overview as a larger sorting table.

Storage

The rotating shelf system used today is preferable because it enables storing a large amount of orders in an organised manner. Operators are used to the system and if sleeves will be stored in a similar way this also favours the suggestion because it means one system less to learn.

2.6. Additional question marks

A range of possible issues have been dealt with in this chapter but some additional questions to consider are:

- How will the cliché including the slitting line be handled while sorting and when mounted in the mounting machine?
- What machine settings are needed for making sure empty lanes are not mounted? How is each sleeve related to the pile of clichés? Or is it possible to always add blank clichés on the empty lanes?
- Can tape be mounted where there are empty lanes?

3. Task Analysis extracts

During the in depth study on sorting tasks all tasks related to sorting was extracted from the main task analyses and updated and extended with new and more detailed information. This new task analysis was then used in the creation of a sorting related task analysis for the Easy ITS process.

Task Analysis of tasks related to sorting, Pre-press Lund

Order preparations

1. **Customer Sales Representatives**
   - **1.1.** Order arrives from customer to Tetra Pak
   - **1.2.** CSR (Customer Sales Representatives) plans co-prints by coordinating designs to fill out one sleeve for each colour, i.e. one order.
   - **1.3.** CSR sends the production-order to the production planner
2. **Production planning**
   - **2.1.** Update production plan (morning and afternoon)
   - **2.2.** Call to customer folder archive to announce that there are new orders to prepare
   - **2.3.** Order paper and other supplies for the orders
3. **CFA, Customer folder archive**
   - **3.1.** Receive information of new orders (by phone call or a red text in P2 informing that new plan has been saved)
   - **3.2.** Update P2 to see new orders (New orders lack status in P2. Orders in P2 are organised based on priority)
   - **3.3.** Prepare customer folder (Done for each design within an order)
     - 3.3.1. Open the production-order file and save on desktop
     - 3.3.2. Open computer program for adding bar-codes
     - 3.3.3. Load production-order into program
     - 3.3.4. Add bar-code to production order
     - 3.3.5. Print production-order
     - 3.3.6. Delete files from desktop
     - 3.3.7. Change order status in P2 to '*file ordered*'
     - 3.3.8. Place production order in corresponding folder retrieved from rotating shelf (if new design, new folder is created with print from digital files office. If previously used but updated print, a new reference print is added to the folder)
     - 3.3.9. Production folder is placed on "out-shelf" categorised by order number
4. **Digital files**
   - **4.1.** Detect information of *file ordered* from P2
   - **4.2.** Go through the digital décor files and pick out the correct versions
   - **4.3.** Send digital files to cliché making department
   - **4.4.** Print out reference printout of new or updated décor/design versions
   - **4.5.** Deliver new reference printouts to CFA
   - **4.6.** Change status in P2 to '*Film in stock*'

Cliché Making

1. **Plan plate layout**
   - **1.1.** Load order
     - 1.1.1. Open computer program (P2)
     - 1.1.2. Choose order (needs to be confirmed in P2)
     - 1.1.3. Print manufacturing report

1.2. Organise print on plate
- 1.2.1. Open computer program (Backstage)
- 1.2.2. Open computer program (Merge)
- 1.2.3. Download files belonging to order (Backstage → Merge)
  - 1.2.3.1. Specify files corresponding to design nr on manufacturing report
  - 1.2.3.2. Specify number of files of each design to rip
  - 1.2.3.3. Download/Rip files (Backstage → Merge)
- 1.2.4. Organize décors in plate layout manager (Merge software, regards to space optimization)

1.3. Finalize order
- 1.3.1. Name the plate
- 1.3.2. Export plate layout to Imager (and Cutting table)
- 1.3.3. Fill out and sign manufacturing report
- 1.3.4. Change status in P2 to *'Cliché Processing'*

Before the next task the clichés will be produced, processed, dried and cut.

2. Sort cut plates (after cutting)

2.1. Sort cut plates belonging to order in a stack
- 2.1.1. Gather all plates with the same design
- 2.1.2. Sort plates according to colour within the design, following the order on the manufacturing report
- 2.1.3. Place all clichés belonging to one order in a stack
- 2.1.4. Place manufacturing report on top of pile

2.2. Control finished plates
- 2.2.1. Measure relief thickness (not for all plates)
- 2.2.2. Fill out and sign manufacturing report
- 2.2.3. Check that number of cut plates for that raw plate is correct

2.3. Add possible register plates (mark with size)

2.4. Change status in P2 to *'Cliché in Stock'*

2.5. Place finished stacks on trolley and then on rotating shelf

Mounting preparations

3. Retrieve cliché order

3.1. Identify waiting order in P2

3.2. Collect clichés and manufacturing order from rotating shelf

3.3. Collect customer folder and production order from CFA

4. Sort cliché order

4.1. Plan line and colour order by filling out checklist on manufacturing order

4.2. Sort clichés
- 4.2.1. Place clichés belonging to the same sleeve/colour in one pile

4.2.2. Use loupe to check that décor number and plate number on clichés correspond with the checklist
4.2.3. If co-print, place clichés belonging to one sleeve in a pile, in the order they will be mounted on the sleeve (left to right).
4.2.4. Write the colour on the first cliché for each colour in pile

4.3. Cut off lane numbers on clichés for the technical colour sleeve
4.4. Cut off month and year mark on to technical colour sleeve
4.5. Double check that sorted clichés correspond to checklist
4.6. Check additional information
4.6.1. Check that register line is included in pile
4.6.2. Check that required register plates are included in the pile

Mounting

5. Retrieve and check order
5.1. Select waiting order in P2 (*Cliché in stock*)
5.2. Retrieve corresponding order pile from cabinet
5.3. Assign Microflex machine with recipe that fits format
5.3.1. Look up recipe code from table next to machine (based on package size, sleeve type and number of lanes)
5.3.2. Assign recipe code to Microflex
5.4. Take all clichés belonging to one sleeve from order pile
5.5. Double Check Sorting
5.6. Check that correct sleeve types are placed on nearby trolley

In between these steps the clichés will be mounted onto the sleeves for the complete order.

6. Check completed sleeve
6.1. Compare mounted sleeves to manufacturing order
6.1.1. Check that register line is mounted
6.1.2. Check that month, year and lane marks are cut off on technical colour clichés
6.2. Sign masking tape on each sleeve with employee number
6.3. Visually check the sleeve
6.4. Sign manufacturing report belonging to sleeve order

7. Report completed order
7.1. Place manufacturing order in file folder
7.2. Take a delivery report and fill out the checklist
7.3. Place delivery report in customer folder
7.4. Place customer folder on sleeve trolley
7.5. Change order status in P2 to *'Ready to start'*

Task Analysis of tasks related to sorting, Easy ITS

Order preparations

The task is not changed from existing pre-press.

Cliché making and mounting

1. Plan plate layout

The task is very similar to existing pre-press.

Questions to consider:

- Do the operators have to manually add date and lane marks?
- Can it be automatically implemented in the software program?

2. Sorting

2.1. Retrieve manufacturing report

2.2. Sort clichés

2.2.1. Sort clichés according to colour

2.2.2. Sort clichés according to lane number (lane 1, lane 2…) within each colour.

2.2.3. If there are empty lanes in lane 2 place a blank cliché in that position in the pile

2.2.4. Place a plate with information about P-order and colour on top of each sleeve/colour pile

2.3. Assemble all piles belonging to one printing order, décor facing up and code in the lower right corner.

2.4. Finalize order

2.4.1. Fill out and sign manufacturing report

2.4.2. Place order in cabinet with manufacturing order on top

2.4.3. Change order status in P2 to Cliché sorted

3. **Plate mounting (preparations related to the clichés)**

3.1. Retrieve order

3.1.1. Select waiting order in P2 (*Cliché in stock*)

3.1.2. Check that correct sleeve types are taped and placed on vertical trolley

3.1.3. Retrieve corresponding order pile from shelf

3.2. Check order

3.2.1. Select plates belonging to a maximum of six sleeves

3.2.2. Double Check sorting

3.2.2.1. Check order of cut plates

3.2.2.2. Check orientation of cut plates

3.2.2.3. Check that blank plates are included and placed correctly

3.3. Load plates

3.3.1. Open plate mounter back door manually

3.3.2. Pull out plate trolley

3.3.3. Retrieve correctly stacked cut plates pile

3.3.4. Place cut plates in plate trolley

3.3.5. Position plate trolley in plate mounter
3.3.6. Close plate mounter back door manually

4. **Finalize order**
   4.1. Retrieve sleeve trolley
   4.2. Control sleeve
      4.2.1. Position sleeve in quality control machine
      4.2.2. Perform sleeve check
         4.2.2.1. Check that register plate is mounted
         4.2.2.2. Check clichés with month, year and lane marks are correctly placed
         4.2.2.3. Check that stepping is correct
         4.2.2.4. Check for overlaps
         4.2.2.5. Check that cliché edges are attached to tape
      4.2.3. Perform Quality Control
      4.2.4. Sign Sleeve
         4.2.4.1. Write P-order and colour number on piece of masking tape and place on sleeve with matching colour.
         4.2.4.2. Sign masking tape on each sleeve with employee number.
      4.2.5. Unload sleeve and place on sleeve trolley that will contain full order batch
   4.3. Report completed order
      4.3.1. Sign manufacturing report belonging to order
      4.3.2. Place manufacturing report in shift production folder
      4.3.3. Take a new order report and fill out the checklist
      4.3.4. Retrieve customer folder from customer folder archive and place checklist in customer folder
      4.3.5. Place customer folder on sleeve trolley
      4.3.6. Change order status in P2 to *Ready to start*

Transport sleeves on trolley to storage area for printing

Appendix 4
In depth study: Manual handling

This chapter will be initiated with a description of how lifting and the handling of heavy items are done in Pre-press today. Issues with the existing system are identified followed by recommendations and proposals for how manual handling may be minimised and/or improved in the Easy ITS process.

1. Manual handling in Existing Pre-press (Lund & Limburg)

In both processes, new and old, manual handling can be divided into two main groups; sleeve handling and plate handling. The analysis in this chapter is based on the Pre-press production sites in Lund and Limburg and most of the information in is gathered through interviews and the visits to the production. For additional clarification official instructions were studied.

Both types of material handling will be described and connections will be made to the *Theoretical framework* (D:8) where recommendations, taken from for example Tetra Pak's ergonomic handbook, are outlined.

1.1. Overview

Initially, the extent of manual handling will be identified and outlined by the use of previously produced HTAs.

Lund factory

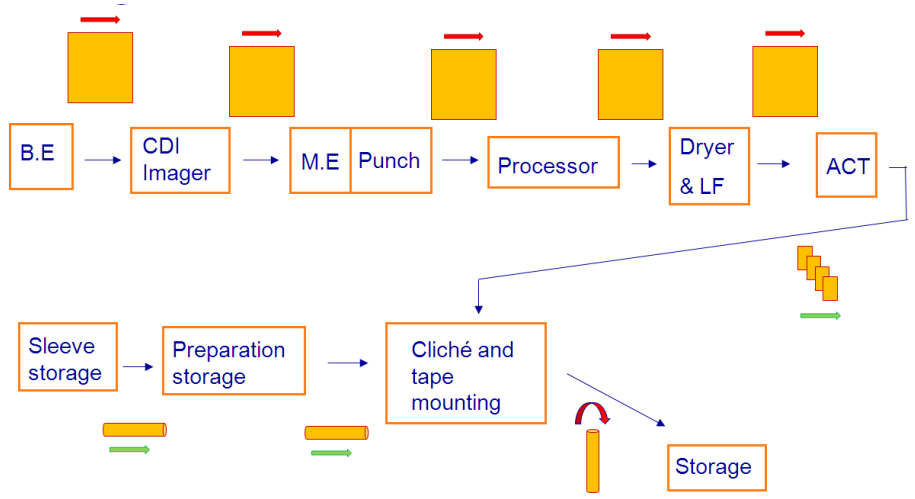


Figure 4.1 Manual handling Pre-press Lund

The main issue in Lund is handling the large plates, much since this is done along the majority of the Cliché Making process. For sleeve handling the critical handling takes place when sleeves are taken to

and from storage and when the mounting machine is loaded and unloaded. Red arrows represent tasks that are especially critical for the operator and should be redesigned. For sleeves, the most critical tasks involve twisting and changing from a horizontal position to a vertical or vice versa. Green arrows are rated as less serious in this context, but are not necessarily preferable.

Limburg factory

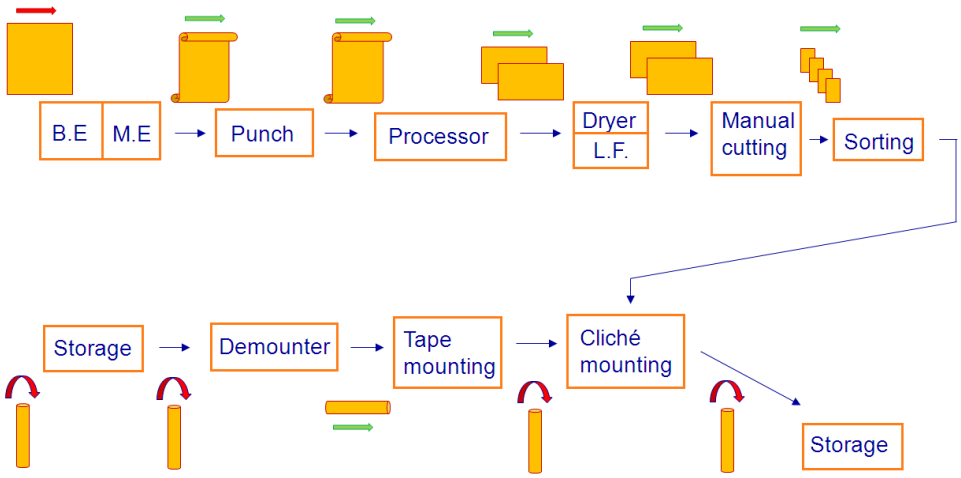


Figure 4.2 Manual handling Pre-press Limburg

In Limburg the handling of large plates was considerably less for two reasons. The machine units were placed closer to each other and on a line, additionally the plate was rolled together for some tasks. Before using Dryer and Light finisher the plate was cut in smaller half which made the handling much easier. This was possible since a manual cutting table is used here as opposed to the automatic version in the digital process in Lund that requires the whole plate to cut correctly.

1.2. Plate Handling

In Lund, after the plastic cover has been removed and it has been imaged, it is less stiff and may be carried either straight or folded (see picture 4.1). However, after imaging the décor on the plate is easily damaged and can therefore not be touched or collide with other objects. After the plate has been processed it needs to be handled with gloves because it is covered with a solvent from the processor. It is also still very easily damaged. The use of gloves, the slippery surface of the plate and its fragility affect how the plate may be handled. Finally, when the plate has dried, the décor reliefs are solidified and it is not as fragile.

The plate is 1m x 1.5m, 1.7 mm thick and weighs approximately 4,5 kg. Depending on where in the process it is, the plate should to be handled differently. In its initial condition, it is covered with a plastic cover which makes it quite stiff and it therefore needs to be handled held flat to avoid breaking.

Postures

In Lund the recommendation is to carry the plate by holding it diagonally. By doing this the risks of walking into something and damaging the décored side of the plate is minimised, see picture 4.1. This lift forces the operator to hold out the arms wide, far from the body, with high elbows. When placing

the plate on one of the machine surfaces the operator has to reach far above the surface to let go off the plate as straight above as possible to avoid creases and the plate sticking to the surface.

Picture 3.1 To the left, a diagonal grip and to the right gripping the plate along the long side

Another way to carry the plate, no longer recommended due to identified issues, is to hold the long side corners (see picture 4.1). This method led to a range of issues related to décor damages since the décored surface was held away from the body and hence easily could collide with other objects. Furthermore, when using this technique the plate needs to be held high up not to touch the floor, resulting in a lift above shoulder height. The plate is placed on the surface by swinging it upwards while still holding the edges. This has a high risk of causing breaks on the plate before it has been processed. Additionally swinging the plate like this can cause ergonomic issues in back and shoulders due to the sudden and explosive movement.

When placing and removing the plate from the machines the large size of the plate makes it difficult for the operators to stand in a balanced way when lifting it which is highly linked to ergonomic issues. This is especially an issue when placing the plate above the high imager, in the high Light Finish drawer or in the low Dryer drawers. To avoid touching the décor and cause fingerprints, the operators hold the plate with a pinching grip, which is highly unfavourable. When taking concern to the weight and size of the plate and the frequency of the task the handling of large plates is a large issue and facilitating actions should be implemented.

In Limburg the plate is kept in the same exposure for both back exposing, placing analogue films and main exposing. After exposing, the plate is rolled together and both punching and fastening of the plate in the processor is done when the plate is in a roll. After processing, the plate is cut in half and the two halves are handled separately in the following process steps. All of these reasons highly decrease the issues related to plate handling in Limburg.

After the clichés have been cut out they are collected, sorted and piled. Since the two sorting activities take a long time, it is very important that this handling is done with appropriate equipment on an appropriate height. In appendix 3 (*In depth study: Sorting),* issues with sorting tasks are more have been discussed and solutions proposed.

Storage

In Lund, the plate box is placed on a trolley with lift functionalities so that it may be raised to an appropriate height. This way bending is not required when retrieving and loading the Back Exposure with a new plate. When the clichés are done they are delivered to the Cliché Mounting department and stored in a rotating shelf system (paternosterverk). There are no other buffers throughout the process.

1.3. Sleeve Handling

For placement in the machines the sleeves' length and inner diameter is constant for the different sleeve formats. The outer diameter however, varies to be able to fit different package sizes. Sleeves with a small outer diameter are very light in comparison to sleeves with a large outer diameter. As an attempt to better meet regulations concerning heavy lifting, Lund factory have increased the use of light weight sleeves. The weights of the different variations of sleeves vary from 5 to approximately 25 kg.

Postures

A sleeve is preferably held in a horizontal position, see picture 4.2 (left). This way the operator's back can be in an upright position and hard gripping is not required since the sleeve in a way rests on the operator's hands. This position is beneficial because the sleeve can be carried close to the body. Nonetheless, careful balancing by adjusting grip and compensating force is needed not to drop the long sleeve.

Due to the high weight of the sleeves it is important that the sleeve can rest on a large area of the hand to avoid balancing it on the fingertips.

Picture 4.2 To the left a picture of an operator holding the sleeve horizontally and to the right vertically

At times the sleeve is placed in an upright position, for example when the vertical trolleys are used, see picture 4.2 (right). This forces the operator to turn it into a horizontal position by twisting the wrists.

Handling loads when not standing straight and balancing the weight with a twisting grip, should be avoided. This is even more important when large and heavy weights are involved, as in this case, therefore these tasks should preferably be avoided or ergonomic aids be provided. Additionally lifting a sleeve from a vertical position requires a lot of hand force since the grip is done by pressing the hands together towards the sleeve. This lift is very likely to cause discomfort in hands and wrists.

Loading of the Microflex is similar in Lund and Limburg. Interviews have shown that pushing the sleeve onto the shaft requires a lot of force, especially if the sleeves are a bit worn out. It is therefore important to have good air compression on the machine shaft and to regularly maintain and replace worn out sleeves.

The weight of the sleeve itself is often close to the unacceptable limit and also, the shape of the sleeve highly affects the difficulty of the task. As mentioned above, the length of the sleeve requires balance to hold it steadily which forces the operators to constantly adjust the grip. When taking concern to the weight, the length of the sleeve and the frequency of the task, sleeve handling is a serious issue and lifting aids should be implemented or the number of lifts minimised.

Trolleys

Horizontal trolley Lund

In Lund a horizontal trolley with 12 shafts is used along with a vertical with six shafts. The horizontal trolley is placed close to the Microflex machine when mounting and sleeves are removed from the trolley for mounting and then put back.

One issue with this trolley is the height of the shafts. According to the majority of the operators the highest shafts are placed too high and cause discomfort in shoulders. They also express that the lower ones are placed too low. Both lower and higher measurements are outside recommendations given in Tetra Pak's ergonomic handbook, see *Theoretical framework* (D:8). Another issue is the closeness of the shafts that make it difficult to fit the largest sleeves without damaging them. The large diameter of the shaft helps keep the sleeves symmetrical but leads to that loading requires higher precision.

When discussing the trolleys with the operators, many of them had suggestions on different designs that would improve the placement of the sleeves. One idea involved a rotating system, others fewer shafts on each trolley, or a wider trolley including three instead of four levels and four instead of three on the width. To deal with the limited space between the large sleeves they have imposed a rule that when sleeves with the largest diameters are used they should be placed with one empty shaft in between to avoid clashes and damages.

Despite the high weight of the trolleys the operators had no issues manoeuvring them, except for a few incidents where the trolley had rolled over an operator's foot. To protect their feet when transporting the trolley the operators are not allowed to pull the trolley backwards, behind them. Additionally a protective barrier has been implemented on the trolley that is a plastic protection between the trolley edge and the floor to prevent the operators from running over their own or someone else's feet.

One of the trolleys used in Limburg is a larger horizontal trolley with 16-20 shafts. The horizontal trolley is usually placed in the same room as the Microflex machines but not directly close to it. The reason for this is that it would be crowded to place the large trolleys next to the machines. Sleeves are therefore placed standing on the floor next to the Microflex when it is time for mounting.

The height of the shafts on these trolleys is unacceptable since the highest ones are above shoulder height forcing lifts with arms above the head. Also each shaft is slightly upward tilting which make each lift even higher. The shaft on this trolley has a diameter of approximately 5 cm which means loading does not require much precision.

Vertical trolley Lund and Limburg

The vertical trolley (figure 4.3) has been used in Lund for a while and the factory in Limburg has chosen to invest in it to replace their larger horizontal trolleys. In Limburg the plan is to use these trolleys for all sleeve types.

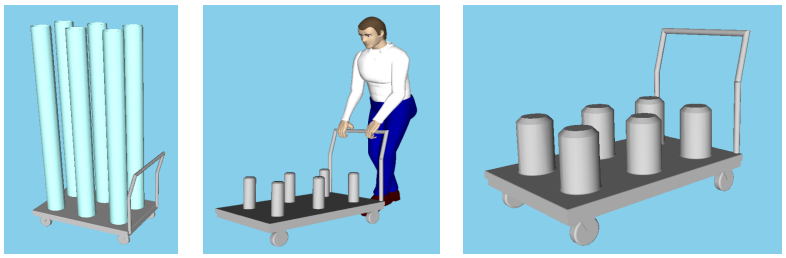


Figure 4.3 Vertical sleeve trolley

Compared to horizontal trolleys the vertical takes up relatively little floor space and is easier to manoeuvre. However, one large issue with this trolley is the direction of the sleeve that forces the operator to perform a twisting movement when loading and unloading a sleeve. The height of the cones forces the operator to lift each sleeve above that height to unload them.

In the Easy ITS process the vertical trolley will be used for transport and temporary sleeve storage.

Storage

The sleeve storage in Lund is a fixed shaft shelf and poses a very large issue to the operators. In order to retrieve a sleeve from one of the higher shafts the operator needs to climb a latter. When using this latter the operators need to stretch to reach the sleeve, balance while unloading it from the shelf shaft, and finally carry the heavy load while climbing down. Loosing balance in this position can result in serious injuries. In addition the lower shafts are placed too low. The horizontal placement is beneficial since it reduces twisting. To facilitate the use of the shelf heavier sleeves are placed on the most appropriate heights.

In Limburg sleeves are today stored standing upright on the floor in a room across the production hall, but this will be replaced by storage on vertical trolleys. This means that today each lift requires twisting to place the sleeve on a horizontal trolley before taking the sleeves to the Cliché Mounting area.

2. Manual handling in Easy ITS

This chapter will include a description of how manual handling could look after the implementation of Easy ITS. Possible issues are highlighted and finally recommendations on how the situation can be improved are provided. When studying the Easy ITS line, team members were interviewed and to get additional expertise Tetra Pak's ergonomist Ulrika Welin was consulted.

2.1. Overview

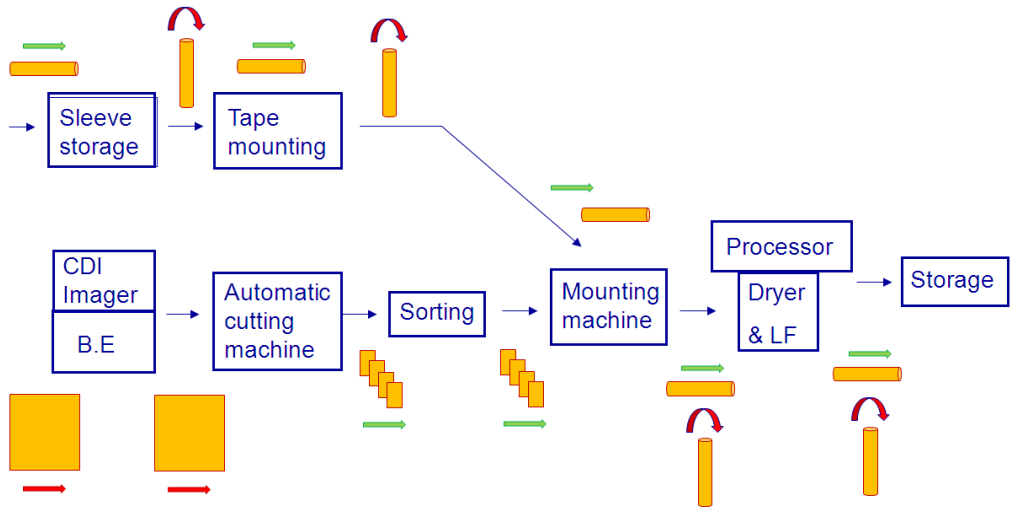


Figure 4.4 Manual handling Easy ITS

In Easy ITS, handling of both plates and sleeves will be largely changed compared to the existing Pre-press process, see figure 4.4. Since the plate is mounted to the sleeve earlier in the process sleeve handling will increase while plate handling will decrease. However, due to the combination of several machines the total number of tasks including manual handling of sleeves and plates is decreased.

For sleeve handling the most critical tasks are still connected to changing the grip of the sleeve to or from a vertical position which highly links them to the use of trolleys.

2.2. Plate handling

All plate handling in Easy ITS take place before and after Imager combi. In the first step the plate is retrieved from a box and then placed on top of the machine from where it is loaded automatically. The height of the Imager combi might be an issue since it will be too high for shorter operators. From the Imager combi, the imaged and exposed plate is retrieved from a tray and transported to the cutting machine where it is cut. Due to this the handling of the large plates is widely decreased in the Easy ITS line.

As discussed in the previous chapter, sorting in Easy ITS will only be done once, but there is a large risk that the stickiness of the clichés will increase. This makes appropriate equipment for sorting even more important, see appendix 3 (*In depth study: Sorting)*

2.3. Sleeve handling

Sleeve handling in Easy ITS will increase and hence it is more important to identify and provide aid for critical tasks already on an early stage. Sleeve handling is related to loading the tape machine, mounting machine, the processor and finally the machine used for quality control and moving sleeves to and from a trolley. With the current tape machine used in the Easy ITS project a range of ergonomic issues have been identified, out of which some are related to moving the sleeves from the machine shaft to a vertical trolley (or vice versa).

The processor is loaded by placing the sleeve on a horizontal rest. This action is better for the operators than sliding the sleeve onto a shaft, but it is still important to have an appropriate rest height to facilitate placement.

Mounting trolley Easy ITS

In Easy ITS, a horizontal trolley is already used when loading sleeves into the mounting machine, see figure 4.5. This trolley differs from the previous horizontal trolleys because the sleeves are not placed on shafts but rest at the two ends instead. This increases the precision needed to place each sleeve, but at the same time each sleeve can be easily lifted from the trolley. The highest row of sleeves is at a very good height whereas the lowest requires lifts below 400mm which is against recommendations given in the Tetra Pak's ergonomic handbook. This trolley has a handle along the long side, for moving it into the mounting machine, but no handle for pushing it from the short side.

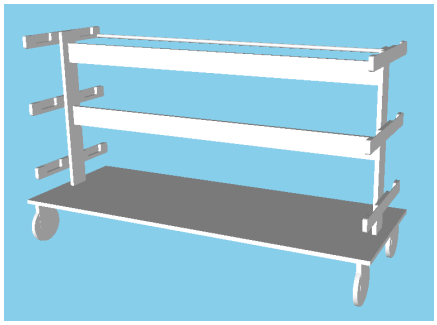


Figure 9 Horizontal sleeve trolley

3. Actions to facilitate manual handling

In this section actions to improve manual handling in the Easy ITS line are discussed.

3.1. Actions to facilitate plate handling

Initially there are many solutions in the Pre-press today that Easy ITS should consider implementing in the new line as well. The trolley used in Lund, with a lift built in for raising the supply of plates to a good height, could for example also be used in Easy ITS.

The height of the Imager combi out feed tray is similar to the cutting machine height and sliding the plate between the machines could possibly be a solution. The placement of the machines should be

done with concern to the in and out feed placement on the machines, they should also be placed close and crossing pathways be avoided.

3.2. Actions to facilitate sleeve handling

To reduce sleeve handling in Easy ITS it would be favourable to expand the use of the mounting trolleys. This way the task of moving sleeves from one trolley to another could be avoided on two occasions. Additionally twisting could be avoided both when moving a sleeve from the taping machine to a trolley and from the trolley into the processor.

However if this trolley should become the primary trolley some adjustments should be done to the design. Firstly it would be favourable to design the trolley so that it would be manoeuvrable from the short side as well by adding a handle there and making sure the wheels have full rotation. Secondly the height of the lowest position is an issue and solutions that involve rotating the sleeves have been discussed during ergonomic audits and with members of the Easy ITS team. Unfortunately the construction of the trolley is not easily altered since it is connected to mechanics of the mounting machine.

One way to improve the work height of the mounting trolley, suggested during the final interview with Tetra Pak's ergonomist, would be to place it on an adjustable platform when loading and unloading sleeves. This solution would improve the operators' working height but is quite complicated to implement if it should be provided at several places in the process, but is nonetheless an implementable solution. Additionally, there are large risks that this solution would not be used if too time consuming.

Another solution under investigation is to build in the function of picking up sleeves from a trolley, and unloading them onto a trolley, in the processor. This would eliminate most sleeve handling between the mounting machine and the processor since the sleeve would remain on the trolley. This solution is not possible to implement for the validation testing but could be possible for future factories using the Easy ITS process.

When lifting and carrying the sleeves it is important to have enough space to be able to adopt the most suitable posture and to easily be able to manoeuvre the sleeve. One example can be seen in figure 4.6 below where the operator has troubles manoeuvring since two machines are placed too close.

Figure 4.6 Operator loading sleeve, picture from Navisworks and Pro/ENGINEER Manikin

Several issues when loading the sleeves onto the Microflex machines were detected in Lund Pre-press. These issues were partly related to the lack of space in front of the machine but also worn out sleeves, which is why it is important to regularly check the sleeves and replace old ones.

For future storage solutions a rotating shelf system for sleeves would be preferable and is available on the market. This is a strong recommendation from both the Master Thesis authors and ergonomist Ulrika Welin because the system in Lund today is not acceptable. The rotating shelf would deliver the sleeves at a good height requiring no twisting, reaching or bending of the back. An additional advantage is that the sleeves would be protected from dust and wear and tear damages related to inappropriate sleeve handling.

Appendix 5
Task Analyses

1. Task Analysis Lund

Below follows the task analyses made for the departments in Lund. Information is taken from interviews and observations along with education material for Pre-press.

Pre-press Lund, Cliché Making

1. Plan plate layout

1.1. Load order

1.1.1. Open computer program (P2)

1.1.2. Choose order (needs to be confirmed in P2)

1.1.3. Print manufacturing report

1.2. Organise print on plate

1.2.1. Open computer program (Backstage)

1.2.2. Open computer program (Merge)

1.2.3. Download files belonging to order (Backstage → Merge)

1.2.3.1. Specify files corresponding to design nr on manufacturing report

1.2.3.2. Specify number of files of each design to rip

1.2.3.3. Download/Rip files (Backstage → Merge)

1.2.4. Organize décors in plate layout manager (Merge software, regards to space optimization)

1.3. Finalize order

1.3.1. Name the plate

1.3.2. Export plate layout to Imager (and Cutting table)

1.3.3. Fill out and sign manufacturing report

1.3.4. Change status in P2 to *'Cliché Processing'*

2. Back exposure

2.1. Load plate

2.1.1. Make sure lid to back exposure is open

2.1.2. Retrieve plate

2.1.3. Place in back exposure

2.1.4. Close lid

2.2. Press 50 second button that also starts the machine

2.3. Machine running (50 seconds)

2.4. Indication job is completed (X)

2.5. Unload plate

2.5.1.Open lid

2.5.2.Lift plate by holding edges

2.5.3.Place plate in pile ready for imager

3. Imager

3.1. Load plate

3.1.1.Push cover open

3.1.2.Retrieve plate

3.1.3.Place on top of imager

3.1.4.Remove plastic cover

3.1.5.Fasten plate in imager

3.1.5.1. Position plate edge on imager drum

3.1.5.2. Fasten first edge of plate

3.1.5.3. Rotate drum one lap

3.1.5.4. Fasten other edge of plate

3.1.6.Close cover

3.2. Start Machine

3.2.1.Push button to reposition laser

3.2.2.Select order from list on computer

3.2.3.Press start on machine interface

3.3. Machine running (15 min)

3.4. Indication job is completed (display)

3.5. Unload plate

3.5.1.Open cover (button)

3.5.2.Demount plate

3.5.2.1. Loosen edge of plate, releasing fastener

3.5.2.2. Place plate edge on top of imager

3.5.2.3. Rotate drum one lap

3.5.2.4. Loosen other edge of plate, releasing fastener

3.5.3.Remove plate from imager

3.5.4.Close cover (or new directly)

4. Main exposure

4.1. Load plate

4.1.1.Make sure lid to exposure is open

4.1.2.Retrieve plate

4.1.3.Place plate on main exposure surface

4.1.4.Punch holes on edge inside exposure

4.1.4.1. Position to the left side of exposure (within limits)

4.1.4.2. Punch holes using pedal on floor

4.1.4.3. Position in the middle of exposure again

4.1.5.Close lid

4.2. Press *12 minutes* button that also starts the machine

4.3. Machine running (12 minutes)

4.4. Indication job is completed (beeping sound)

4.5. Unload plate

4.5.1.Open lid

4.5.2.Remove plate from exposure (Lift by holding edges)

5. Solvent processor

5.1. Load plate

5.1.1.Make sure processor is unoccupied

5.1.2.Retrieve plate

5.1.3.Position plate

5.1.3.1. Put plate on surface

5.1.3.2. Attach plate to fastener

5.1.3.2.1. Place fastener appropriately

5.1.3.2.2. Pull plate close to fastener

5.1.3.2.3. Attach hole on plate to correct plug on fastener

5.1.3.2.4. Attach all holes along the plate

5.1.3.3. Push fastener with plate forward

5.1.3.4. Manufacturing report put on whiteboard

5.2. Start Machine by pressing start on interface/display

5.3. Machine running (ca 10 min)

5.4. Indication job completed (blinking yellow light)

5.5. Unload plate

5.5.1.Pull plate sideways to detach from fastener

5.5.2.Remove plate from processor (Lift by holding edges)

5.5.3.Reposition fastener

6. Dryer

6.1. Load plate

6.1.1.Open drawer

6.1.2.Retrieve plate

6.1.3.Position plate in drawer

6.1.4.Write information about when finished on board corresponding to drawer

6.1.5.Close drawer

6.2. Drying time (150 min)

6.3. Indication job completed (compare board to clock)

6.4. Unload plate

6.4.1.Open drawer

6.4.2.Remove plate from dryer (Lift by holding edges)

6.4.3.Close drawer

6.4.4.Erase time on board

7. Light Finishing

7.1. Load plate

7.1.1.Open drawer

7.1.2.Retrieve plate

7.1.3.Position plate

7.1.4.Close drawer

7.2. Start machine

7.2.1.Press 12 minutes button (UVA light)

7.2.2.Press 14 minutes button (UVC light)

7.3. Light finishing time

7.4. Indication job completed (Dark display and machine switches off)

7.5. Unload plate

7.5.1. Open drawer

7.5.2. Remove plate from light finish drawer (Lift plate by holding edges)

7.5.3. Close drawer

8. Cutting Machine

8.1. Load plate

8.1.1. Retrieve plate

8.1.2. Clean backside of plate

8.1.3. Position on cutting table

8.2. Start machine

8.2.1. Select order on computer

8.2.2. Adjust cutter head

8.2.3. Press start

8.3. Machine running

8.4. Indication job completed

8.5. Unload cut plates

8.5.1. Reposition cutter head

8.5.2. Collect cut plates

8.5.3. Dispose of waste material

9. Sort cut plates (after cutting)

9.1. Sort cut plates belonging to order in a stack

9.1.1. Gather all plates with the same design

9.1.2. Sort plates according to colour within the design, following the order on the manufacturing report

9.1.3. Place all clichés belonging to one order in a stack

9.1.4. Place manufacturing report on top of pile

9.2. Control finished plates

9.2.1. Measure relief thickness (not for all plates)

9.2.2. Fill out and sign manufacturing report

9.2.3. Check that number of cut plates for that raw plate is correct

9.3. Add possible register plates (mark with size)

9.4. Change status in P2 to *'Cliché in Stock'*

9.5. Place finished stacks on trolley and then on shelf (paternosterverk)

Pre-press Lund, Mounting Preparations

1. Retrieve cliché order

1.1. Identify waiting order in P2

1.2. Collect clichés and manufacturing report from paternosterverk

1.3. Collect customer folder and production order from CFA

2. Sort cliché order

2.1. Plan line and colour order by filling out checklist on manufacturing report

2.2. Sort clichés

2.2.1. Place clichés belonging to the same sleeve/colour in one pile

2.2.2. Check that décor number and plate number on clichés correspond with the checklist.

2.2.3. If co-print, place clichés belonging to one sleeve in a pile, in the order they will be mounted on the sleeve (left to right).

2.2.4. Write the colour on the first cliché for each colour in pile

2.3. Cut off lane numbers on clichés for the technical colour sleeve

2.4. Cut off month and year mark on to technical colour sleeve

2.5. Double check that sorted clichés correspond to checklist

2.6. Check additional information

2.6.1. Check that register line is included in pile

2.6.2. Check that register plates are included in the pile

3. Prepare tape

3.1. Find correct punch template

3.2. Punch tape

3.2.1. Pull out tape

3.2.2. Position tape in tape stack

3.2.3. Cut off tape

3.2.4. Punch tape stack

3.2.5. Throw away tape waste

3.3. Place punched tape in tape pile

4. Prepare masking tape

4.1. Retrieve green plate

4.2. Place 5 different coloured pieces of tape on green plate

4.3. Write P-order and colour number on matching piece of tape

5. Retrieve sleeves

5.1. Check type of sleeve in manufacturing order

5.2. Collect sleeves

5.2.1.Take down sleeve from shelf

5.2.2.Put sleeves on trolley

5.2.3.Transport sleeves to mounting

5.3. Report picked sleeves in computer

6. Finalize order

6.1. Sign manufacturing report with employee number

6.2. Place order in cabinet

6.2.1.Place folder, clichés, punched mounting tape and green plate in one pile

6.2.2.Place pile in cabinet next to mounting machines

6.2.3.Write last 4 numbers of order nr on whiteboard with correct shelf nr.

6.3. Change order status in P2 to '*Cliché sorted*'

7. Take out finished sleeves

7.1. Identify finished order and related sleeves

7.2. Transport sleeves on trolley to storage area for printing

Pre-press Lund, Plate Mounting

1. Retrieve order

1.1. Select waiting order in P2 (*Cliché in stock*)

1.2. Retrieve corresponding order pile from cabinet

1.3. Double Check sorting

1.4. Assign Microflex machine with recipe that fits format

1.4.1.Look up recipe code from table next to machine (based on package size, sleeve type and number of lanes)

1.4.2.Assign code using Microflex interface

1.5. Check that correct sleeve types are placed on nearby trolley

2. Load sleeve

2.1. Open shaft end (button)

2.2. Retrieve sleeve from trolley

2.3. Push sleeve onto shaft

2.4. Position sleeve

2.4.1.Check and adjust positioning of keyhole

2.4.2.Place hand on sleeve

2.5. Close shaft end (button)

3. Mount tape

3.1. Retrieve tape

3.2. Position tape

3.2.1.Use camera to make sure tape is placed parallel to vertical indicator

3.2.2.Place tape corners along keyhole line

3.2.3.Hold out tape end from sleeve

3.3. Fasten tape

3.3.1.Roll roller down the sleeve until the loose tape end faces straight down

3.3.2.Rest roller on table and apply pressure

3.3.3.Grab hold of plastic cover

3.3.4.Rotate sleeve using pedal

3.4. Position machine using rubber spline to tape next lane

4. Mount cliché

4.1. Retrieve clichés

4.2. Position cliché

4.2.1.Position the left microdot vertically and horizontally in left camera eye

4.2.2.Align right microdot vertically in right camera eye

4.2.3.Put pressure on microdot

4.2.4.Roll roller over microdot line

4.3. Fasten cliché

4.3.1.Attach short end with roller

4.3.2.Rest roller on table and apply pressure

4.3.3.Rotate sleeve using pedal

4.4. Position machine using rubber spline to mount next lane

5. Additional mounting

5.1. Attach Masking Tape

5.1.1.Retrieve masking tape plate

5.1.2.Fasten right colour to corresponding sleeve

5.2. Mount slitting line (only for technical colour sleeve)

5.2.1.Retrieve register line

5.2.2.Assign Microflex machine with recipe that fits format

5.2.2.1. Look up recipe code from table next to machine

5.2.2.2. Assign recipe code to Microflex

5.2.3.Position slitting line along vertical line using right camera eye

5.2.4.Fasten slitting line while pushing rotation pedal

5.2.5.Cut slitting line in appropriate length

6. Check completed sleeve

6.1. Compare mounted sleeves to manufacturing report

6.1.1.Check that slitting line is mounted

6.1.2.Check that month, year and lane marks are cut off on technical colour sleeve clichés

6.2. Sign masking tape on each sleeve with employee number

6.3. Visually check the sleeve

6.3.1.Check that stepping is correct

6.3.2.Check for overlaps

6.3.3.Check that cliché edges are attached to tape

6.4. Sign manufacturing report belonging to sleeve order

7. Unload sleeve

7.1. Open shaft end (button)

7.2. Pull sleeve of shaft

7.3. Push sleeve onto trolley

7.4. Close shaft end (button) /reload

8. Report completed order

8.1. Place manufacturing report in file folder

8.2. Take a new order report and fill out the checklist

8.3. Place in customer folder

8.4. Place customer folder on sleeve trolley

8.5. Change order status in P2 to *Ready to start*

2. Task Analysis Limburg

Below follows the task analyses made for the departments in Limburg. Information is taken from interviews and observations during a few days visit.

Pre-press Limburg, Cliché Making

1. Film making

2. Prepare order

2.1. Retrieve manufacturing order

2.1.1. Open computer program

2.1.2. Select order in P2 (depending on priority)

2.1.3. Print manufacturing order 2 times

2.1.4. Put stamp on one manufacturing order.

2.1.5. Change status in P2 to *'Cliché Processing'*

2.2. Retrieve films

2.2.1. Write down design number from manufacturing order to post it and check how many times film will be used (by lighting table)

2.2.2. Collect file with films from file storage

2.2.3. Fill out on film file checklist how many times a certain design will be used

2.2.4. When correct films have been found, compare design numbers on film with checklist.

2.2.5. Clean films with roller on top of light table and place in a pile (correct order).

3. Back exposure

3.1. Load plate

3.1.1. Make sure lid to back exposure is open (opens automatically)

3.1.2. Retrieve plate

3.1.3. Place plate in back exposure

3.1.4. Close lid (button)

3.2. Start machine

3.2.1. Press 50 second button

3.2.2. Press start

3.3. Machine running (50 seconds) (Operator waiting)

3.4. Indication job is completed (Exposure opens (and small sound))

4. Main exposure

4.1. Prepare plate

4.1.1. Turn plate and place again on exposure surface

4.1.2. Remove plastic cover

4.1.3. Organize films on plate

4.1.3.1. Place approximately 6-10 films depending on package size (Try to place so that numbers can be read without unnecessary turning.)

4.1.3.2. Remove dust with rollers

4.1.4.Cover with vacuum sheet

4.1.4.1. Roll over vacuum sheet from role

4.1.4.2. Tape edges

4.1.5.Close lid

4.2. Start machine

4.2.1.Press *12 minutes* button

4.2.2.Press Start

4.3. Machine running (12 minutes)

4.4. Indication job is completed (machine opens (small sound))

4.5. Unload plate

4.5.1.Remove tape

4.5.2.Roll back vacuum cover

4.5.3.Collect films and place in folder

4.5.4.Role together plate

4.5.5.Remove plate from exposure

5. Punch holes

5.1. Place edge of plate in puncher (the rest still in role)

5.2. Punch holes using pedal on floor

5.3. Remove punched out material with hand

6. Solvent processor

6.1. Load plate

6.1.1.Check that cover on processor is open and fastener in position (normal condition)

6.1.2.Retrieve plate (in role)

6.1.3.Position plate

6.1.3.1. Attach plate to fastener

6.1.3.1.1. Attach hole on plate to correct plug on fastener

6.1.3.1.2. Attach all holes along the plate

6.1.3.2. Let go of plate and let hang towards floor

6.1.4.Close cover

6.1.5.Manufacturing report on desk

6.2. Start Machine by pressing start on display

6.3. Machine running (ca 10 min)

6.4. Indication job completed (blinking red alarm and sound

6.5. Unload plate (A & B depending on line)

6.5.1.A: Position wheel table in front of machine exit

6.5.2.A: Manually draw out fastener to place plate on table

6.5.3.A Detach plate from fastener

6.5.4.A: Cut plate in two halves using scissor

6.5.1 B: Fasten fastener to other fastener

6.5.2 B Pull out along special table

6.5.3 B Detach from fastener

6.5.4 B: Cut in two halves using prototype knife with arm

6.5.5 Remove plate from processor

6.5.6 Reposition fastener (leave door open)

7. Dryer

7.1. Load plate halves

7.1.1.Open drawer

7.1.2.Retrieve plate halves

7.1.3.Place plate halves

7.1.4.Close drawer

7.2. Drying time (120 min)

7.3. Indication job completed (*End* on display)

7.4. Unload plate

7.4.1.Open drawer

7.4.2.Remove plate halves from dryer

7.4.3.Close drawer

8. Light Finishing

8.1. Load plate in light finish box

8.1.1.Open drawer

8.1.2.Retrieve plate

8.1.3.Place plate

8.1.4.Close drawer

8.2. Start machine

8.2.1.Press 12 minutes button (UVA light)

8.2.2.Press 14 minutes button (UVC light)

8.3. Light finishing time (X min)

8.4. Indication job completed (*End* on display)

8.5. Unload plate

8.5.1.Open drawer

8.5.2.Remove plate from light finish drawer

8.5.3.Close drawer

9. Cutting Machine

9.1. Retrieve and place plate halves on cutting table

9.2. Position plate beside cutter blade

9.3. Manually cut along all décor edges

9.4. Throw away waste material

10. Sort cut plates

10.1. Organise cliché order

10.1.1. Place clichés belonging to the same sleeve/colour in one pile

10.1.2. If co-print, place clichés belonging to one sleeve in a pile, in the order they will be mounted on the sleeve (left to right).

10.2. Cut of lane numbers on clichés for the technical color sleeve

10.3. Cut of month and year mark on clichés for technical colour sleeve

10.4. Double check that sorted clichés correspond to checklist

10.5. Check additional information

10.5.1. Check that register line is included in pile

10.5.2. Check that required register plates are included in the pile

10.6. Put protective plastic in between clichés

10.7. Control cut plates (occasionally)

10.8. Change status in P2 to *'Cliché in Stock'*

10.9. Place finished stacks on trolley

Pre-press Limburg, Mounting Preparations

1. Retrieve sleeves
    - **1.1.** Check type of sleeve in manufacturing order
    - **1.2.** Check sleeve location in computer
    - **1.3.** Retrieve sleeves
    - **1.4.** Report picked sleeves in computer
2. Demount sleeve
    - **2.1.** Push sleeve onto demounter
    - **2.2.** Get hold of cliché edge using knife
    - **2.3.** Pull off cliché and tape
    - **2.4.** Pull sleeve off demounter
3. Semi automated tape mounting
    - **3.1.** Mount sleeve in taping machine
    - **3.2.** Position tape along keyhole line
    - **3.3.** Adjust roller closer to sleeve
    - **3.4.** Rotate sleeve using pedal
    - **3.5.** Cut tape along fixed ruler
    - **3.6.** Adjust roller
    - **3.7.** Manually remove overlap tape
    - **3.8.** Remove plastic cover
    - **3.9.** Fasten cover piece around taped sleeve
    - **3.10.** Demount sleeve
    - **3.11.** Place sleeve next to mounting machine (check size to be mounted)

Pre-press Limburg, Cliché Mounting

1. Retrieve order
    - **1.1.** Find waiting order in P2
    - **1.2.** Identify correct order pile from cliché area
    - **1.3.** Make sure checklist has been worked through
    - **1.4.** Assign Microflex machine with recipe that fits format
    - **1.5.** Identify that correct sleeve types are placed nearby
    - **1.6.** If co-print, sort out clichés belonging to one sleeve in separate piles.
2. Load sleeve

2.1. Open shaft end

2.2. Turn on air compression

2.3. Retrieve sleeve from trolley

2.4. Push sleeve onto shaft

2.5. Check positioning of keyhole

2.6. Turn off air compression

2.7. Close shaft end

3. Mount cliché

3.1. Position cliché

3.1.1. Position the left microdot vertically and horizontally in left camera eye

3.1.2. Align right microdot vertically in right camera eye

3.1.3. Put pressure on microdot

3.1.4. Roll roller over microdot line

3.2. Fasten cliché

3.2.1. Attach cliché to sleeve by stroking hands over the surface

3.2.2. Rotate sleeve

4. Additional mounting

4.1. Attach masking tape

4.1.1. Write P-order, colour number and employee number on piece of tape

4.1.2. Attach piece of tape to sleeve

4.2. Mount register line (only for technical colour sleeve)

4.2.1. Cut register line in appropriate length

4.2.2. Position register line along vertical line using right camera eye

4.2.3. Fasten register line while pushing rotation pedal

5. Check completed sleeve

5.1. Compare mounted sleeves to manufacturing order

5.2. Visually check stepping

5.3. Visually check for overlaps

5.4. Check cliché edge is attached to the tape

6. Unload sleeve

6.1. Open shaft end (button)

6.2. Turn on air compression

6.3. Pull sleeve of shaft

6.4. Push sleeve onto trolley

6.5. Turn off air compression

6.6. Close shaft end/reload

7. Finalize order

7.1. Change order status to *Ready to start*

7.2. Sign manufacturing order with employee number

Task Analysis Easy ITS

1. Plan plate layout
2. Imager combi (Back Exposure, Imager, Main Exposure)
3. Automatic Cutting Table
4. Sorting
5. Tape Mounting
6. SRTI (Plate Mounter)
7. SRTP (Solvent Processor)

1. Plan plate layout

1.1. Load order

1.1.1.Open computer program (P2)

1.1.2.Choose order

1.1.3.Print manufacturing report

1.2. Organise print on plate

1.2.1.Open computer program (Backstage)

1.2.2.Open computer program (Merge)

1.2.3.Download files belonging to order (Backstage → Merge)

1.2.3.1. Specify files corresponding to design nr on manufacturing report

1.2.3.2. Specify number of files of each design to rip

1.2.3.3. Download/Rip files (Backstage → Merge)

1.2.4.Organize décors in plate layout manager (Merge software, regards to space optimization)

1.3. Finalize order

1.3.1.Name and save the plate

1.3.2.Export plate layout to Imager (and Cutting table)

1.3.3. Fill out and sign manufacturing report

1.3.4. Place manufacturing report on whiteboard

1.3.5. Change status in P2 to *'Cliché Processing'*

2. Imager combi (1 plate)

2.1. Load plate

2.1.1. Retrieve plate from box

2.1.2. Place plate on top of imager

2.1.3. Remove plastic cover

2.1.4. Position plate correctly to enable automatic loading

2.2. Start Machine

2.2.1. Select order from list on computer

2.2.2. Push *Load Plate* button to start loading

2.3. Machine running (including automatic loading)

2.4. Indication job completed (Blinking green light/ imager side table coming out)

2.5. Unload plate

2.5.1. Remove plate from imager side table

2.5.2. Carry plate to cutting table

2.5.3. Reposition imager side table (button)

3. Automatic Cutting Table (1 plate)

3.1. Position plate on cutting table

3.2. Start machine

3.2.1. Select order from list on computer

3.2.2. Adjust cutter head

3.2.3. Press start

3.3. Machine running

3.4. Indication job completed (cutter not moving)

3.5. Unload cut plates

3.5.1. Reposition cutter head

3.5.2. Collect cut plates

3.5.3. Check that number of cut plates for that raw plate is correct

3.5.4. Dispose of waste material

3.5.5. Carry cut plates to sorting table

4. Sorting

4.1. Retrieve manufacturing report

4.2. Collect customer folder from office

4.3. Sort clichés

4.3.1.Sort clichés according to colour

4.3.2.Sort clichés according to lane number (lane 1, lane 2…) within each colour.

4.3.3.If there are empty lanes in lane 3 place a blank cliché in that position in the pile

4.3.4.Add a post-it with information about P-order and colour on each sleeve/colour pile

4.4. Assemble all piles belonging to one printing order, décor facing up and code in the lower right corner.

4.5. Finalize order

4.5.1.Fill out and sign manufacturing report

4.5.2.Place order in cabinet with manufacturing order on top

4.5.3.Change order status in P2 to *Cliché sorted*

4.5.4.Place customer folder on shelf

5. Semi automatic tape mounting (1 sleeve – repeat until full batch)

5.1. Retrieve sleeve

5.1.1.Identify waiting order in P2

5.1.2.Check type of sleeve in manufacturing order

5.1.3.Locate sleeves

5.1.4.Take down sleeve from shelf

5.1.5.Place on trolley

5.1.6.Transport sleeves to taping machine

5.1.7.Report used sleeves in computer system

5.2. Load sleeve

5.2.1.Wind up lever to lift shaft

5.2.2.Open shaft end

5.2.3.Turn on air compression

5.2.4.Retrieve sleeve from vertical trolley

5.2.5.Push sleeve onto shaft

5.2.6.Turn off air compression

5.2.7.Close shaft end

5.2.8.Release shaft lever to let shaft rest on shaft end

5.3. Mount tape lane (repeat 3 times/sleeve)

5.3.1.Position tape roll

5.3.1.1. Position tape roll sideways, to positioning block

5.3.1.2. Place ruler on backside of tape (leaving approx 10mm outside edge)

5.3.1.3. Position tape roll closer to sleeve

5.3.1.4. Position ruler along keyhole line

5.3.2.Fasten tape

5.3.2.1. Position pressure roll to be in contact with sleeve

5.3.2.2. Press rotation button for >360° (creating overlap)

5.3.2.3. Check that tape is aligned at sleeve end

5.3.3.Cut tape

5.3.3.1. Adjust tape roll out from sleeve

5.3.3.2. Use ruler and pen to mark keyhole line on top of tape

5.3.3.3. Cut tape with an angle along marked line, on top of first ruler

5.3.4.Remove overlap tape

5.3.5.Attach tape ends by hand

5.4. Unload sleeve

5.4.1.Wind up lever to lift shaft

5.4.2.Open shaft end

5.4.3.Turn on air compression

5.4.4.Pull sleeve off shaft

5.4.5.Place sleeve on trolley

5.4.6.Turn off air compression

5.4.7.Close shaft end

5.4.8.Release shaft lever to let shaft rest on shaft end

6. Plate mounting

6.1. Retrieve order

6.1.1.Select waiting order in P2 (*Cliché in stock*)

6.1.2.Check that correct sleeve types are taped and placed on vertical trolley

6.1.3.Retrieve corresponding order pile from shelf

6.2. Check order

6.2.1.Select plates belonging to a maximum of six sleeves

6.2.2.Double Check sorting

6.2.2.1. Check order of cut plates

6.2.2.2. Check orientation of cut plates

6.2.2.3. Check that blank plates are included and placed correctly

6.3. Load plates

6.3.1.Open plate mounter back door manually

6.3.2.Pull out plate trolley

6.3.3.Retrieve correctly stacked cut plates pile

6.3.4.Place cut plates in plate trolley

6.3.5.Position plate trolley in plate mounter

6.3.5.1. Adjust positioning toggles

6.3.5.2. Push plate trolley into plate mounter

6.3.6.Close plate mounter back door manually

6.4. Load sleeves

6.4.1.Retrieve sleeves

6.4.1.1. Locate correct batch of taped sleeves already on vertical trolley

6.4.1.2. Transport trolley to front of plate mounter

6.4.2.Open plate mounter front doors (not interface)

6.4.3.Pull out mounter trolley

6.4.4.Load sleeve onto mounter trolley (repeat 6 times)

6.4.4.1. Lift sleeve off vertical trolley

6.4.4.2. Place sleeve on mounter trolley

6.4.5.Remove plastic tape cover (repeat for all lanes and sleeves)

6.4.6.Position mounter trolley inside machine

6.5. Close plate mounter front doors (using machine interface)

6.6. Start machine (using machine interface)

6.6.1.Select plate size

6.6.2.Select sleeve size

6.6.3.Select number of sleeves

6.6.4.Select if any deviations from normal batch (i.e. empty lanes etc)

6.6.5.Select Start

6.7. Machine running

6.8. Indication job is completed (optional)

6.9. Unload sleeves

6.9.1. Open plate mounter front doors

6.9.2. Pull out mounter trolley

6.9.3. Close plate mounter front doors

6.9.4. Lift sleeve off mounter trolley

6.9.5. Place sleeve on vertical trolley

6.10. Transport mounted sleeves to processor

7. Solvent Processor (1 sleeve – repeat until full batch on trolley)

7.1. Load sleeve

7.1.1. Indication that new sleeve can be loaded

7.1.2. Open processor front door

7.1.3. Retrieve sleeve from vertical trolley

7.1.4. Place sleeve on sleeve rest in processor

7.1.5. Close processor front door

7.2. Start machine

7.2.1. Enter machine settings

7.2.2. Press Start

7.3. Machine running

7.4. Indication job is completed (optional)

7.5. Unload sleeve

7.5.1. Open back door

7.5.2. Remove sleeve from sleeve rest

7.5.3. Place sleeve on vertical trolley

7.5.4. Close back door

8. Finalize order

8.1. Retrieve sleeve trolley

8.2. Control sleeve

8.2.1. Position sleeve in quality control machine

8.2.2. Perform sleeve check

8.2.2.1. Check that register plate is mounted

8.2.2.2. Check clichés with month, year and lane marks are correctly placed

8.2.2.3. Check that stepping is correct

8.2.2.4. Check for overlaps

8.2.2.5. Check that cliché edges are attached to tape

8.2.3.Perform Quality Control

8.2.4.Sign Sleeve

8.2.4.1. Write P-order and colour number on piece of masking tape and place on sleeve with matching colour.

8.2.4.2. Sign masking tape on each sleeve with employee number.

8.2.5.Unload sleeve and place on sleeve trolley that will contain full order batch

8.3. Report completed order

8.3.1.Sign manufacturing report belonging to order

8.3.2.Place manufacturing report in shift production folder

8.3.3.Take a new order report and fill out the checklist

8.3.4.Retrieve customer folder from customer folder archive and place checklist in customer folder

8.3.5.Place customer folder on sleeve trolley

8.3.6.Change order status in P2 to *Ready to start*

8.4. Transport sleeves on trolley to storage area for printing

Appendix 6
Interview material

1. Data collection

1.1. Interviews and observations, Lund Pre-press

Interview 1 (mounting & cliché)

The Lund Prepress production includes two main parts and the two apartments are called cliché and mounting. Cliché include all tasks for creating a cut and processed cliché. In mounting which can also be called mounting, the clichés are mounted onto sleeves, cut pieces of tape is prepared for the mounting operator.

At the Cliché department the operators work in three different shifts; morning (07-14), afternoon (14-22) and night shift (22-07). The three shifts rotate each week and the production rest during weekends. Mounting use the same schedule but have four different rotating shifts AND they work every day of the week.

Interview 2 (CFA, mounting)

Operator in charge of customer archives gave us a short introduction to his work assignments and how prepress structures the processing information about produced clichés. X explained how each customer order is checked by X's college and then sent to X who prints a specification that follows the order through the entire process, including printing.

- They no longer reuse sleeves due to the previous implementation of the CDI Imager.
- Once the clichés are produced they are stored and are not mounted until just before it is sent to print.

Without us putting the subject on the table X talked about the human factor in many phases of the process. One example was that a bar code had been introduced to replace automatic setting of the printing machines. Several variables such as cutting vs. punching were included in the barcode which was simply scanned by the machine/operator. To him this was positive because it is most definitely possible that an operator will press the wrong button. He added though that the consequences for a mistake earlier in the chain, for example when information/variables are added to the bar code, result in more serious consequences because the sense of care in controlling each sample is decreased. Too much trust is put into computer data and the material is no longer screened by a trained human eye.

X told us of a visit to Rubiera factory where they used a very different system. Beginning with that they used both CDI and reused plates, but keeping no real record of what they had saved and which were made with the new or the old technique. X also mentioned that they had several inspectors for each

product and in that way making sure nothing went wrong, which in X's opinion is not the most efficient or cost efficient way of doing things.

General comment from the team was about the need for more people working.

Interview 3 (cliché & mounting)

Working in mounting means lifting 40 sleeves per shift, some lightweight. Sleeve storage, lifting from high up, damaged shoulders. Before traverse was used but easier now but with consequences. Discussions on using a sleeve trolley with adjustable height so that it could be placed in front of machine to just slide over, or at least avoid low and high lifts. X had gotten the impression that it was too expensive and therefore not proceeded

80% Target – meaning they must produce at least 80% of possible production rate. If not they must explain why not. Breaks were not included but it was still a stressful situation.

There is a plan to use Twinlock sleeves for all sleeves in the near future which removes the need for both cutting and mounting tape, however it also adds the need to wash the sleeves. Today a machine is used to wash them but before this was also done by hand. Concluding thought that it seemed they had hit a wall in what could be done with mounting as it was today.

Also, the operators had heard about the ITS project and were under the impression that many of their jobs were on the line. This of course creates a tension and a negative attitude towards the project we are working on. This was one big issue that needs to be discussed. Either these types of developments are done in a way that make all members aware of what is going on or it remains closed until decisions are made.

Interview 4 (mounting)

- X said each shift lifts approximately 200 large sleeves.
- Y was very suspicious as to what we were there for and wondering if we wanted to do some actual work.
- Z let us know ovens are too slow, they need 2,5h for each.

Interview 5 (summer worker mounting)

Y told us about Y's summer job at the mounting department at Tetra Pak and helped us clarifying the tasks included in the job and how Y usually performed them. In the mounting department Y did all other tasks but mounting sleeves.

As a summer worker Y experienced that they were often ahead of schedule compared to regular teams, according to Y due to them being young and fresh. Y had been working in Mounting for several summers. When first introduced to the job Y got a walk through by an operator for about two hours and then started sorting clichés, asking questions when something needed clarification. Y didn't use the available instructions the first two years since she found it much easier to ask one of the seniors. The last summer there were a lot of new routines to follow which she learned and clarified with the help of the instruction manuals.

Other issues that came up that may be of interest in this report:

- When washing twinlock sleeves Y said they had 3 min when the washer is running that they often used to perform other tasks despite the rule against it. This rule was to make sure that the washer was running as much as possible.
- Depending on how alert Y felt Y preferred different tasks. Priming twinlock sleeves was more tempting when she felt a bit tired because then she could relax while the machine was working whilst punching tape was better when Y felt alert.
- Each order was finished before the shift walked off. If there was not time to finish another order they just waited for the time to pass.
- At each shift change the two teams have 12 minutes (6min of each shift) to discuss issues and fill out a form/report to management.
- Y usually prepared two orders at a time, if they were simple and not to complicated, meaning Y served each mounter parallelly.
- One ordinary trolley can take sleeves for two orders and the smaller version of trolleys, where the sleeves are placed vertically they are only allowed to placed the two lighter types of sleeves due to ergonomic reasons.
- The staff had been complaining about headaches for quite some time and it was discovered that it was due to the chemical used in manually washing the twinlock sleeves, which was now replaced by the automatic sleeve cleaner.
- Y also recommended us to follow an operator in real life, that way they will think of everything they do, this is difficult to go through when they are not on site.

Interview 6 (mounting)

During this visit the team working had only maintenance tasks such as cleaning and serving the machines which offered a great opportunity to discuss their workplace.

New computer, asked for over a year back, now they finally got a new one.

Information about instructions was gathered. All instructions are developed and updated by the employees themselves after careful discussions among all shifts. These instructions are then available on a server and may be printed out when changed.

Y told us that the focus on the 80% target rated had been shifted towards minimizing the amount of stops later in the process, in printing that is. When the production rate target is too much in focus mounting personnel tend to mount without doing their final sorting, checking that the clichés are in the correct order. From now on the management wants the mounting personnel to focus more on quality than quantity.

General complaints about the 12h shift that take place during the weekends. Obviously the workload will be distributed in a way similar to the way of 8h shifts, meaning the 80% target. This of course means that more needs to be produced during these 12h than 8h which is very logical but seems to create stress among the workers.

During this visit two workers discussed the bad luck of getting two weekends with the 12h shift twice this month and explained that it is inevitable that this happens to one shift over a period of one year.

Interview 7 (Mounting)

Y had worked there for "only" ten years. Y did not take fitness training as many other employees but did not yet experience back pains etc. But noted that many of colleagues who had been there longer than her especially complained about pain in their shoulders.

Y noted the high weight of the largest sleeves, and that with Twinlock they would be made easier/lighter. Y also noted that the weight itself was not the main problem but the shape of the sleeve and also the lack of space available when handling them.

Interview 8 (summer worker cliché)

X explained that in the cliché area the tasks were divided into three main parts. Operator 1&2 were in charge of one line each going from planning sheets to loading and unloading the processor. Operator 3 in each shift is in charge of cutting, which was according to X the most unpopular one. This third person would sometimes load the driers, move sheets from drier to light finishing, cut the sheets and also sort the orders before placing them in the rotating shelves.

The task of unloading the processor and loading the ovens/driers was a bit ambiguously distributed amongst the operators. This depended on who was free at the moment, which was usually one of the two first operators.

To prepare producing an order Operator 1&2 must:

- Retrieve order:
  - Open program 1 to download order and convert files.
  - Open program 2 to download order files and start building up sheets
- Sheets are filled with patterns/clichés/prints from different orders in order to minimize spill. This is a skill that is improved over time as the operators learn which sizes are best combined.
- When sheet is finished the file is sent to both CDI Imager and to the table next to the cutting table.
- Each file is given a name, often the name of the operator and a number.
- Usually the shift leaves 2-5 (often 3) orders waiting in the system so that production can start even though new sheets have not been planned.

The rest of the task for operator 1&2 include:

- Placing a sheet in back exposure for approx 50s. Opening this and other exposure unit is usually not a problem since it is not closed between unloading and loading. Several back exposed sheets may be piled up. This routine differs between teams. It is a critical task to carry the sheets since they are quite stiff in this part of the process and therefore easily break or bend ("knäckta" – 1000skr/sheet)
- Moving this sheet to load into the CDI, and start the imaging there. After the CDI is finished this shows either in the machine display or by a decreased sound.
- After the CDI the sheet is placed in the main exposure unit for approx 12 min. When this is finished a distinct sound is given out. When sheet is finished (according to the rules this should be done before main exposure is started) here it is slided to the side of the machine by the

operator where holes are punched out by stamping on a pedal. X mentioned there had been a lot of problems with the punching, leaving pieces of cliché sticking onto the sheet.

- Next the sheet is carried to the processor where it is attached to a fastener (kam) by putting knobs into the punched holes along one of the sides. Jennifer said that it was possible to attach the whole side from one side of the table but that required some severe leaning. On one of the machines it was a natural movement to come from one side and then move over to start the machine. The other was placed in an opposite direction meaning that many leaned instead of walking around when using that processor.
- The fastener is then pushed into the machine. It is not possible to start the processor if this fastener is not pushed far enough into the machine. Processor is started using a touch screen interface.
- When the processor is finished, after approx 10 min, a blinking yellow light in the large room indicates this. This light can be seen from the computers where sheets are planned.
- Processor is emptied and sheet is placed in a dryer drawer. Drawer is preferably opened before sheet is carried there. It is carried with pattern side facing the body and to then place the sheet with pattern side up in a drawer also requires heavy leaning. This is difficult also in the lower drawers due to lack of balance.
- When drawer is filled a whiteboard close to the dryers is filled out and 2,5h ahead is calculated manually by looking at the clock in the room. For one of the dryers the whiteboard is placed between two dryers, meaning it is a bit more difficult to fill out and therefore this is left for later.

The flow in these tasks is quite natural but if/when there is a stop in the dryers this obviously create a problem in the processor queue. X told us that it was possible to trick the machine and load and start a new sheet before the machine was unloaded.

Another comment was that for operator 1&2 it was planning the sheets that was time consuming. If this task was not included, one person would be enough for that task. Handling the sheets was described as “otympligt”. An additional task was to measure the relief on the cliché. This was done a bit ambiguous to.

Tasks for operator 3 in charge of “cutting” include:

- When a sheet is taken out of a dryer drawer and put in light finishing the time on the whiteboard is wiped out.
- Light finishing is always placed on the top drawer. For the new machine it sometimes requires two people to place sheet. When loaded, two buttons are pushed, 12 & 14 min. On the machine there is a countdown.
- It is custom that no order is left unfinished and therefore they sometimes stop unloading like 20 min before the next ship to make sure they have time to cut and sort the last sheet. Other sheets are left in the dryer.
- After light finish the sheet is placed on the cutting table. Placing the sheet can be tricky since it is a bit sticky. Difficult but not impossible to adjust placement.
- The sheet is cut according to a file with the same pattern that was sent to the CDI. This file is collected in the computer and sent to the cutting table. The sheet is cut and leftovers disposed of.
- After it is cut the clichés are sorted into piles with one order in each. Often it is also sorted in colors. In this step it is also checked that all clichés in the order is there.

- When order is completed its status is changed in the computer next to the manual cutting table.

Interview 8 (mounting)

Stepping is the difference with which each cliché is placed on the sleeve. Stepping is selected in the computer on top of the mounting machine.

- Check for size on order paper
- Check for size in papers by computer
- Chose settings on computer

Time pressure on drying clichés, orange clichés are better. Now using green, very sticky and stiff, not dried long enough. Clichés can easily get folded and thereby damaged. Suppliers recommend drying 5-6h. In factory they dry for 2,5h.

X also discussed trolleys, wished for trolley with 4 sleeves horizontally and only three vertically because highest and lowest was difficult to handle. This would amount to 12 sleeves/trolley, same as today. Maneuvering trolley was ok.

- Shifts: X was pleased with working a rotating schedule with shifts. One complaint, saying rather work more days in a row and free at least two days in a row, but that these types of opinions are very individual. “If you can’t adapt, you never will”
- X had a damaged right arm and was not able to lift elbow above shoulder. Automatic mounting roller was very helpful but only used on Twinlock sleeves.
- X also mentioned that the punching tools for tape were not all perfect; meaning X sometimes had to place them a bit off line. X said that X had learned which sizes would most likely be skew.
- If the tape would end before the last cliché it would need to be remounted.
- Orders coming from London, roughly cut, needed to be cut again and then mounted.
- One color is the technical colour and contains a register plate. The sleeve with this color also needs a register line to be attached at outer right end.
- Problem with Twinlock was that even though they prime each cliché, due to a not sharp enough edge (not cut properly, unsharpened knife) there will always be some air at the outer end, that will loosen when it get in contact with colors/ink.

Interview 9 (cliché)

X had worked there for approx 20 years, on different departments.

- The team explained the procedure and what was done to the cliché sheet from beginning to end.
    - Cliché receives back exposure in separate machine
    - Cliché is put into CDI where black layer is cut through
    - From CDI into main exposure (same type of machine as back exposure)
- X noted difficulties with punching the pattern for the fastener in the processor. Small pieces of cliché stuck on to the sheet causing problems further ahead in the process.
- When planning the sheets, different orders were put on each sleeve to minimize spill. After a while they tend to learn which sizes go well together.
- Y discussed the software programs used to plan each sheet:
    - Need to continuously reload inbox for orders to see if there is a new order and check due date.

    - Now they were approx one week ahead of schedule
    - When there was a new order this showed in a box in the lower left corner of the screen and also visible in the excel sheet but only by words… Possible to make colored boxes, easier to see?
- Both of them carried the sheets with pattern facing out from their body, against recommendation. Probably to be able to load oven drawers easier.

Interview 10 (cliché)

X explained that when it is a single print order they sort by colors, which is also the correct order for mounting. It is when it is a co-print that it is still need to be resorted by mounting. This is because cliché sort by design and color for example 3st A022. In co-print one sleeve is filled with different designs for example 3xA022 and 2xA024.

Of course they could do it the right way directly but it would be very time consuming. She also mentioned that with large co-prints a lot of space was needed for sorting. The light table in mounting was sometimes filled with piles of clichés.

X disliked the new dryer because it had six drawers, unlike the old with only five. More drawers meant higher top drawer and lower lowest drawer. Being shorter than average X sometimes found it tiring to lift with elbows above shoulders which was also a common work posture.

Thought budget had decreased. Stressful situation, missing time could not be won back.

When working at the dryer and cutting it was pretty much standing all day, never sitting down. Bumper carpet she didn't think help much, often stumbled on them though. Within her shift they most often changed positions during a working period/day.

Interview 11 (mounting)

- Orders are usually finished before shift change.
- The next shift came there approx 50 min before shift change. They had then reached the EE target, producing 84%, 76 sleeves. In a way the stopped working then. Comment that boss now puts more focus on EE so they did little AM but then boss put pressure on AM.
- AM scheduled every Monday 8-10 so all shift do it.
- Productivity demands are doubled when orders use Twinlock sleeves. This doesn´t consider the fact that service needs to do priming and cleaning sleeves when Twinlock is used.
- Trolleys were discussed. In Lund they are only allowed to use the vertical six sleeve trolleys for the smallest lightest sleeved. Lifting a heavy sleeve when it is vertically positioned is very bad.
- When an order is finished it is reported in P2 as ready to start and sleeves as placed outside the prepress area on trolleys. They are then picked up by someone not belonging to prepress.
- A new alarm light was installed at the entrance where trolleys with finished and unfinished sleeves are brought in and out. This light was supposed to alert the carrier that someone was coming out. This new installation both annoyed the workers because it started each time they walked in as well, not serving a purpose.

Interview 12 (mounting)

X tells us that they have received an update on one of the mounting machines. The update includes an automatic feeding system of the automatic pressure roller. The new system means that the roller moves into place just by the push of a button. This takes longer and X didn't like the fact that X couldn't adjust the time or reposition the microdot if it slipped out of place, due to the fear of jamming fingers under the roller. X also discussed in more broad terms the importance of including the operators in development. Several people were against the new installation but still it was done, with the result that very few wished o use the machine.

X described that we should all work collectively, as a family where everyone gets a say when a change is coming up. It doesn't work if one family member just walks out and buys new furniture without consulting the rest of the family on for example what colour they prefer. When asked about WCM work X said it was one way but it still does not include everyone, just a couple of people.

Interview 13 (mounting) 18 October 2010

Interviewee was summer worker and work extra during semesters

ZZ has both worked in the cliché and in the mounting department for 2 summers and sometimes during week-ends. ZZ has worked with different shifts and with different collegues.

Issues:

- The chemicals (lubricants) when using the processor in the cliché department has caused coughing
- There is still glue from the clichés left on the twinlock-sleeves when handling these. If it is heavy ZZ wants to place the sleeve on his arms and ZZ thinks this might be bad.
- There should be a lamp that indicates when the washing of the twinlock-sleeves are done. The washing takes 2 minutes and the priming of the clichés approx 1 min per turn; therefore it should be possible to do other things and sort when the washer is running. By using this time there is time to do more things during a day. Some people only do one thing at once and then the other one serving does all the other things which is not very time-efficient (for neither one).
- Motivation: Many operators work to accomplish 0/0 (not more). But extra workers often do more in a day. But that is understandable since extra personnel work maybe 3 months and permanent employees for years…
- Should have space to sort in the room where priming is done because then it would be possible to sort when the machine is running rather than running like crazy.
- In the dryer (cliché department) the top drawer is too high and the bottom too low.

Interview 14 (mounting) 18 October 2010

- It would be possible to prime with double efficiency if it would be possible to prime both sides at once. This could be done with two primer-nozzles instead and by placing the entire cliché in the machine instead of just the edges.
- The people that are doing the mounting are supposed to double-check the sorting done in mounting preparations and compare with the written order on the paper. Sometime this is not

done. It would approximately take 1,5 min per sleeve to check, i.e. 8 min per order which is almost time to do one more order per day.

1.2. Interview checklists, Limburg Pre-press

Interview checklist, Production Manager

The checklist is preliminary but we wish to conduct a semi-structured interview focusing mainly on the working process, productivity demands, operator involvement, ergonomic issues and process difficulties.

Basics:

- How long have you been working at Tetra Pak? Current position?
- Working process
- How involved are the management in designing the working process?
- Development of process taking place?
- What is the procedure for changing the design of a task?
- What type of education material exists and who makes it?
- What are the procedures for introducing new employees?

Shift work:

- How is the shift work organised?
- Is each shift as productive?
- Same productivity demands on day and night shifts?

Productivity:

- Productivity goal? (What happens if goal IS NOT reached? What happens if goal IS reached?)
- Increases in productivity demands? (Recent, continuous?)
- Motivational methods used? Commission on productivity?

Ergonomic issues:

- Have any especially demanding tasks (physically/mentally) in the working process come to your attention?
- Sick-leaves, complaints on hurting shoulders etc?
- How are these complaints handled?
- Are there lifting aids? If there would have been, do you think they would be used? (Why/Why not?)
- What is being done to minimize ergonomic issues?

Process difficulties:

- Error statistics?
- What are the most common reasons for production stops? Both in prepress and later in the production process?

Interview checklist, Cliché making operator

The checklist is preliminary but we wish to conduct semi-structured interviews focusing the working process, ergonomic issues and process difficulties.

Basics:

- How long have you been working here?
- How long have you worked within this shift?
- How do you feel about shift work?
- 12 hour shifts?

Working process:

- What tasks do you perform in the process?
- Are any other tasks distributed within your shift?
- Favourite/least favourite task?
- Please describe, Step by step, a typical workday?
- How are process steps distributed within the shift? Strict or collaboration?
- Educational/Information material? (Design, extent, used?)
- What are the procedures for introducing new employees?

Shift handover:

- Are there differences that you know of between shifts working methods?
- Always finalize one order before shift end?
- Leave prepared orders for next shift?
- Contact, discussions, giving tips between shifts?

Ergonomic issues:

- Are there any especially demanding tasks to perform?
- Have you experienced any physical discomfort resulting from your working tasks? Or heard from colleagues?
- Are there lifting aids? If there would have been, would they be used?
- Is there any aid you would wish to have?
- Any other aids developed here? If so, by whom?

Process difficulties:

- Communication between parts of the production, like printing?
- If something is damaged, procedure?
- Most common reasons for production stops later in the process? How are you informed? Stops due to machines or “human actions”?
- Sleeve handling; Trolleys used? Shelves and sleeve storage? What types of sleeves are used? Use of air compression? Etc.
- Do you have difficulties with any machine interface? Any interface you prefer?
- Procedures when machine malfunctions? Can you sometimes repair yourselves?
- Cliché handling, working heights, fragile surface?

Productivity:

- How do you feel about the workload?
- Is there a clear production goal? What happens if goal is not reached? What happens if goal IS reached?
- Over the years, workload increased or decreased?
- Different workload between tasks? Which is heaviest?

Workplace environment:

- Over the years, work situation improved?
- Motivation to work harder? What is done?
- Team spirit? Methods to improve?
- Contact with management? If need new clothes etc?
- Is there anything you would you like to change?

1.3. Interviews and observations, Limburg Pre-press

Interview 1 (cliché)

Working background

This operator had been working in Tetra Pak for a total of eight years and during the last three years Y started working in the Prepress department, mainly in cliché making. Even before Y got this job Y had volunteered to help in pre press when they were short on workers, mainly because he was eager to learn new things and had therefore gained a growing interest for working in Prepress. Y also felt working the prepress department was best placement of what positions he had tried so far. Why do you like working at Tetra Pak? Y appreciates the possibilities to improve and change how tasks are executed and also the possibility to be versatile and constantly learn new things.

Shift work

Y explained that within each shift they used job rotation, meaning that within the shift they divided the schedule into blocks over which different tasks were distributed. This rotation within shift is in reality decided by the workers and some shifts prefer to stay at the same working stations while others follow the rotation schedule. Y feels there are very little differences between the different shifts, especially since the new standard has been introduced. As an example Y mentioned a standardized way of placing the films so that marks/codes could be found easily without needing to flip the films.

Extra work

One thing that is different between the shifts is how extra work is planned. Within Y's team newly incoming films where organized simultaneously with simpler orders, for example single prints whereas in other shift they would stop everything else when sorting and organizing the new film prints.

Extra work such as changing lamps is preferably done when a shift is short on workers. This is because when lamps in the exposure is changed the new lamps need some hours to burn before they may be

used for production, this is why it is best plan this so that they can burn when a shift cannot use the machine at full speed anyway.

Tasks

Within cliché making Y has no preferences among the different working stations although Y mentioned that some of the older people in mounting obviously did not prefer lifting and rearranging the 18kg sleeves.

Y also think that it is most important and demands more focus when an order is just started, including tasks like finding the correct order, collecting folder with films and compare the numbers. Placing the films on plates is the most critical and important task and therefore it is important that it is standardized.

A new and better system, according to Y, has been introduced where the most important information is gathered on a single piece of paper. This helps in checking if design and color number have changed since it was last used. This information is written in very small letters on the film.

Y also mentions that the cutting table sometimes becomes a bottleneck (when 200 base is produced, meaning small sized clichés). Since the same person is supposed to sort the clichés before they are sent to mounting, the other members help to do the sorting. The reason is that sorting is very important since the people in mounting rely on it…

Ergonomic issues

Y mentioned a few ergonomic issues within prepress. To start with the lid to the exposure cannot be opened far enough meaning one need to bend back and neck to lean over the table if one is too long. Also, since the plate is so large you must stretch to reach the other end of the plate. Y feels this situation would be better if the exposure unit would be adjustable in height. Y also explains that there had been discussions on attempts to solve this but since there was not a easy solution to the problem it was not carried out. Another ergonomic issue is the temperature in the production hall. Due to a different air pressure within the prepress hall, air would flow out as soon as someone opened the door, making it hot in the summer and cold in the winter. Another issue with the ventilation is that one exhaust is placed directly above the cutting machine where one person is usually standing still for a whole shift. Y thinks neck problems could be connected to this.

Y Explained that a lifting device had existed but it was not used and had then been taken away again. When discussing the new trolleys Y thinks it is a good idea and that they will work better mostly since they take up less space but also makes the point that it is always an issue to get used to new things/equipment/etc..

What would prepress look like in your perfect world?

Y imagined a single line where all machine units are placed in a row, in a correct order, including shelves with material and mounting machines. Y also wants more space and no dust flying around in the room.

Education

When learning new procedures there are education material to use, Y know of this, but explains that it is much easier to ask coworkers which is why problems may continue down the chain despite changed instructions.

When learning a new machine and its interface Y had experienced that the person installing the machine had explained how it worked and how to use it and that there was an instructions manual available afterwards as well so Y saw no larger problem with learning a new machine. Y also think it is easy to use the interfaces.

Problems

Internal claims are used for larger problems but smaller issues good communication is sufficient according to Y. There is according to Y good communication between the different areas within prepress.

Interview 2 (cliché)

XX has worked on Tetra Pak since 1989. Until 1993 XX worked with TP REX and after that as a carrier driver for 7 years. In 2000 XX started working at Pre-press in Limburg.

Shift work

XX does not like working night-shifts (one of the reasons XX previously preferred working as a carrier driver, because they do not work nights). XX finds them “horrible” and “hard to get used to”.

Favourite tasks

In the beginning XX did not have a favourite task, preferred doing different things and be flexible. In XX’s shift a colleague prefers cutting and XX the exposure and there is a lot of flexibility among block rotation.

In 2002 the plan was to make cliché making and cliché mounting operators more united and give everyone the same education and knowledge within the two areas. The goal is that 4/6 operator in a shift have skills to work in both areas. XX says that this was the plan but feels that it is not fully working. Firstly he feels that everyone is not fully educated to do the other tasks (difficult to educate each other). Further since they are still separated in two areas and have not learned enough and since it is not regularly used then you forget again. [K: It needs regular rotation to work]. Finally (specifically to XX’s shift) the other operators are not completely healthy and cannot perform all tasks.

Ergonomic issues/Issues machines

- Exposure - Lean over when place films on plate in exposure (Since cover does not open enough and exposure unit quite low).
- Cutting - Lean over and standing still for whole shift.
- Processor - A bit tricky with the new processor table as it does not always work but it is better.
- Dryer - Only one year old but handling is good and it does not smell. Sometimes there are technical issues that often had to be solved by the supplier.
- XX found it to be very few problems with exposure and processor.

Machine lines

XX says that it 99% of the cases the operators do the tasks within their own "machine line" (E: Exposure 1, Processor 1 or Exposure 2, Processor 2). It is only when a machine is broken they use the other side's machines.

P-orders

2 orders are printed. 1 2-sided paper to mounting and the other one to the box in cliché making that will later be used for inventory.

Shift change

Question: Where can material be left in production when there is a shift change? There are no critical points in the production and they can just continue where they are.

Communication with management

XX feels that he can influence and has a good contact with management. For example they got a new shelf for old film formats after mentioning the space problem. This took between 3-4 months.

Workload

XX finds the work quite stressful if it is full production, especially for the cutter. The operator working by the cutting machine has to cut approximately 40 plates per shift and also sort these. Sometimes the dryer is full from the shift before and then the cutter has even more to do.

There is no clear production goal per shift but the target is to expose approximately 17 plates per shift and exposure. (K: 2x17=34)

There are also some extra tasks that have to be done within the shifts. One example is film sorting. Each day (around 7:00) approximately 20 new films are sorted and organised in the shelves. The distiller also has to be managed.

Perfect world

- In the perfect world there would be a robot so that they would not have to work ☺
- It would be really good always to have a full shift with 2 full lines. It would also be really good with help for the cutter (high workload see above).
- With more space there would be room for another table by the processor and a new ceiling (E: ceiling is one of the reasons for the dust causing dirty print).

Difficult/challenging tasks

Cleaning the processor; The chemical Flexosol that is used in the processor has a strong smell. Before the processor was cleaned thoroughly once a week but with the strong smell this made XX and others feel dizzy. Now it is cleaned once every morning instead and the practice is to wear a mask. The new processor is more closed (and therefore better) than the other one. XX (and others) informed work council about the smell of Flexosol and it is under investigation.

Home-made solutions

- Roller - A roller to remove dust from the films have been found online.

- Extension on window scraper – Long arm fastened to window scraper used for removing air under vacuum sheet when exposing plates.

Interview 3 (Prepress management)

Interviewee started as trainee and has had many positions. Production Manager since 2008.

About WCM ("the WCM philosophy")

The development of new methods using WCM is always based on some kind of loss. WCM has 2 steps; the pillar organizations and problem solving done by the operators.

The pillar organization is attacking and employing losses and unplanned stops. They define the problems into small details and then give to a group of operators to solve. There is usually also a member of the pillar organization or management within this group. (The goal is to build up an info system, analyse and abnormalise, build up solutions, follow up new procedures and look at possible reoccurrences, cycle…)

Standardised procedures have started to be developed. Dirty and missing prints are a problem brought to attention by TP globally. A global initiative has been started and 8 teams have developed standards to avoid this issue.

This WCM (E: The WCM audit we got to visit 10/11/10) was a bit different. Here the goal was instead to mount and produce clichés in the right way. Normally when there is a break-down WCM would use standardized tools to look at this, they would from this define actions and then act upon these (4M and 5Why). In theory there would be done an analysis and counter measures would be thought of and investigated. In practice a quick fix is instead instated to fix a break down and after this a quick analysis is applied.

In WCM, operators are taken from their normal working environment to analyse the issues. Today a lot of issues are brought to the surface and analysed, before this was not common and many operators are not used to this. They tend to like it if they can find easier procedures that can lower their workload (i.e. not just to understand the machine/why something is happening). 80 % of the operators tend to participate in this and 20-30% can be said to be driving it. In the factory there is also a suggestions scheme where suggestions for working procedures can be "put". Changed procedures are documented on OPL and WIM. These can be found in the factory but also in the AM room for new employees. In the AM room all working steps are documented.

Management

The production manager is responsible for the whole factory production. Directly below him there are 5 shift leaders. Then there is one team leader for each group in each shift. For example has pre-press (making and mounting) one team leader for each shift.

Internal claims

There is an internal claim system to report issues. Here can, for example printing, report a claim about something being wrong when the material arrives from pre-press. *"We want many, to know what to work with."* He says they need to know what to work with, so it is important with these claims.

Shifts, Mounting and cliché making

He says that the mounting and making groups used to be separated, but he wants to work towards a pre-press group with pre-press operators instead. To do this cliché makers need to know how to mount (etc). Before cliché making was viewed as something easier (being done by old and weak). Hence it has become more valued and seen as more and more important for the whole process. The pre-press production is only one shift and has one team leader. (E: like ITS….)

The shifts sometimes stops working towards end of shift because there is not enough time to finish a whole order. Because shifts work differently it is not good to mix shifts within order. But it is more possible when the same standardized procedure is used by all shifts. One of the differences between day and night shifts are that the operators have more time after 5 o'clock in the afternoon. During the day they have a lot of extra tasks and visits from managers. He says that the operators can be as productive during the first 2 night shifts during a shift scheme but that they easily get tired towards 2:30 late in a shift cycle.

Productivity goals

In Germany it is not allowed to have number/person, i.e. packs/head. Instead they in pre-press have a number of the average sleeves produced per day. This is varying per day. When he had said something about 9 orders per shift per day the operators tended to stop working once they had reached this goal.

Today average or something ok/good is approximately 27 orders per day and the maximum possible for the machines are approximately 36.

The target will go up and have larger peaks at the same time the order size will decrease.

It is hard to plan the orders in advance and he says the planning is "lucky" if it can be done more than 24 hours in advance.

Cliché storage

Today approximately 3% of orders are reusable and stored in a cliché stock (50% co prints….) There can be issues with using reusable due to different thickness which can become a problem when the design is a bit more complicated because of different pressure.

Ergonomics

Improvements are done; one example is rubber carpets. Before there was a crane in the ceiling carrying heavy sleeves, today there are not heavy anymore. There is also air compression…

XX is certified in WCM also including ergonomics. The employer is not allowed to know ergonomic issues the employees have instead they get information from insurance ½ year later. The employer is forced to find something different if the employee only can lift a specific amount or is in any way disabled. Preventive measures at Tetra Pak Limburg are gym, sport clubs and also discounts to go swimming.

Short interviews (during observations)

- Ordered new sleeve trolley (same as in Berlin = the vertical trolleys here) to replace existing (high horizontal trolley slightly upwards angled).

- 6 operators in a normal shift 3+3, the goal is that 4 out of 6 operators on each shift can do all tasks
- There is no problem with damaged clichés between exposure and processor. The cliché is not fragile between these two steps. In the Limburg factory they rolled the cliché together after the exposure and then let it fall towards the floor to unroll when fastened to the processor.
- The most critical process step for the clichés is between the processor and the dryer.
- A special knife have been constructed by the operators to use when cutting the plate in halves after the processor (longer arm and better ergonomically).
- Two manufacturing orders are printed. The order has one column for each (colour/lane), before this was printed on one page each which was more confusing. The back of one manufacturing order gets a stamp and the nr of the used processor is noted. The order is then left in a blue paper organiser on the desk between the processor and dryers. Cutting can then collect the order from here when sorting the plates. Only having one sheet instead of multiple was done a few weeks ago to make sorting easier and to only have to sort once.

- When cutting is done the manufacturing order information can be collected in the blue organiser. The plates are here organised lane by lane and put in piles together with the manufacturing report (protective plastic is also placed between each plate). This sorting should be the only necessary sorting for mounting (hence the operators in mounting should also check the order and the plates before they mount).
- The mounting is done in 3 mounting machines. In the mounting area 2 operators are mounting and 1 is taping and removing old plates from the sleeves.
- The tape mounting is done on a semi-automated taping machine (regi-taper), where the tape is put on in three lanes (extra wide tape that is special ordered). The machine is no longer manufactured so when the machine is broken they have to fix it themselves. Hence they will try to replicate the machine themselves.
- When taping, they lay the tape overlapping and then a ruler is automatically positioned towards the sleeve. (The sleeve is turned using a pedal on the floor.) The operator then cut along the ruler. They have to cut deep enough not to ruin the tape when removing the excessive material (including overlap). At the same time large scars in the sleeve should be avoided. When the whole sleeve was taped the protective cover was removed. Finally one of the cover was rearranged to avoid touching the sticky surface too much before mounting.
- The work towards autonomous maintenance has different goals depending on task performed. The goal is that the operators understand the process of the machine and can link parameters with outcome. This is implemented in the skill-matrix.
- The productivity per day is approximately 130-160 mounted sleeves. The goal in cliché making is 27 finished orders per day and the machine capacity is 36 orders per day. But it is not allowed to count the productivity per shift or operator. (They have documentation about productivity/day.)
- The sound from the processor can be turned off on symbol on the processor display. The sound also stops when the plate is starting to be removed from the machine (when doing this the processor lamp turns green again).
- When exposing, the films are first cleaned on both sides. When they are positioned in the exposure the top surface is cleaned again (order a bit different depending on operator).
- The exposure is blowing out air when running which causes a draft.
- The exposure opens when finished (and small sound).
- Issues with the ceiling due to over pressure in room.

- When organising the films on the plate there are recommendations on a pin board. The recommendations are pictures on how the films should be organised to maximise the plate usage depending on package size. If an order does not fill an entire plate dummy plates (later mounted in mounting to avoid an empty lane 2 (?) in printing) can be added or can orders be mixed on multiple plates.
- When removing the plate and cutting it after the processor (CSL PP Flexo 4260-P) the operator has to lean into an awkward posture.
- Issue: Scratches on top of plate when removing it from the processor, solved with homemade table.
- Plates are positioned above the dryer before they are ready to be placed in light finishing/cutting.
- Issue: pin holes in cliché
- Shift change: Gather and talk for a few minutes before

2. Validating interviews

2.1. Lund Pre-press, Cliché Mounting

Computer system

- Order system need to be updated by operator several times a day. When order list is changed planning should call and let mounting know this is not always the case.
- Pop-ups and constant updates of the running order causes irritation and at times that a waiting order is missed.
- Screen / computer frozen several times a day.
- An incorrect status in P2 is not at all common but it happens a few times/year.
- Not sure if clichés are in storage even if status is *cliché in stock.* Before this was ticked off on a paper, now it is included in P2 system. If an order is not in the shelf when it should be it usually causes quite a big problem.
- Request for a system where one can tick off if customer folder is in archive or not. It happens that the customer is not where it should be which of course create a problem which takes time to solve.
- Status could be set as *mounting* when an order is already being mounted but is not yet finished, but this function is not always used.
- Request for another status that customer folder and production order was prepared. Another status needed is for when something like a register plate is missing, order is already taken out and started on but not yet in mounting.
- There are two separate production order lists to be followed to find a waiting order, one for each printing machine in Lund. This is not really important for either cliché making or mounting and these lists could therefore be combined into one.

Written communication

- Handwritten checklist – could just as well be done automatically because the mounting plan is already set in P2, differently to as it was some time back were the mounting operators decided how each cliché would be mounted. It happens, though rarely, that it is filled out incorrectly which cause problems. Request for increased space on handwritten checklist.
- Visibility of cliché/décor number is very bad. Discussions on using larger digits had taken place but not lead to an improvement. Loupe is rarely used because it is too time-consuming. Light-table is definitely helping.
- Mounting is usually ahead 24 hours with orders. The general productivity demands were not possible to follow if all routines should be followed as well.
- The system with coloured masking/plastic tape for each sleeve to communicate colour and design to printing is working well. It happens of course that some colour runs out but then a white tape is used instead. Wrong information is also written sometimes but this usually does not create a problem.
- A new system was introduced for placing prepared orders. Closed cabinets keep out light and dust and each shelf has a corresponding place on an adjacent whiteboard on which the four last digits for an order is written. In this way an order can easily be found. This system was said to be working very well.
- Mounting have an additional checklist that is filled out when and order is completed. This checklist is then placed with the customer folder following the order to printing.
- The customer folder archive receives a bundle of folders after each shift that needs to be sorted. This could preferably be done differently to save CFA some time.

Other

- Lowest shelf in the storage cabinets was not preferable but was working.
- Register line used to be attached to a cliché but this was changed due to the programming of the cutting machine. Mounting operators would prefer the old way since it is now a cause for frustration and more time consuming. Slitting has also complained on the accuracy of the line. Problems like losing grip and cut the wrong length would go away if it was attached to a sleeve.
- To avoid being hit by and automatic carrier when transporting finished sleeves out to printing a blinking red light starts when doors to the main hall is opened. This was introduced when the carriers started running the opposite direction.
- Sorting
    - When discussing sorting of clichés the possibility to sort differently already after cutting would be preferred. It was also suggested that it would be easier for the one sorting in cutting if the sheets were planned by sleeves or colour and not by décor, this would make sorting co prints a lot easier.
    - Considering lane and date numbers on the clichés these could easily be included already in the imager. This is another thing that has stayed since analogue process where mark was taped over before exposing. Date mark would not influence sorting at all whereas lane marking would mean that the clichés for the technical colour needs to be sorted by lane as well as colour.

  - After sorting is performed a double check is done by the mounting operator before mounting, even if it was sorted by him-/her –self. A while back there was a procedure to look through the codes with a loupe and a flashlight on each cliché when an order was finished, this was however changed since it was too time consuming.
- Most critical tasks are making sure the correct sleeve is mounted in the right place and that there are no airbubbles or creases when mounted.
- Productivity demands
  - For mounting preparations the demand is 6 orders/operator and shift, i.e. 12 orders/shift. This should not be a problem despite co-prints and Twinlock ratios.
  - Reaching the EE goal for mounting is not reasonable if everything should be done thoroughly and according to routine.
  - Taking time gives results in the way that fewer orders need to be redone but goals are not always met.
- When mounting the operator often only rest on one leg for long periods of time since one foot is used for pedal. This leads to uneven
- For ordinary sleeves printing sees to that old clichés are pealed of the sleeves. For Twinlock however they are peeled off by the mounting preparation operator in prepress which leads to sore fingertips. There are gloves that work but that are not resistant to fluids.

Handling material

- Stickiness of clichés varies from time to time, despite same drying time officially. They are not damaged by tearing apart but increasingly difficult to handle. Use of protective plastic in between would mean to much extra work to one interviewee.
- The amounts of sleeves are not always enough for large orders. It is therefore important to make sure there are sleeves enough for an order before the order is started.
- Back, shoulders and thumbs are sore sometimes, colleagues also complain about it from time to time. Cause are both mounting, handling sleeves and other tasks.

Equipment

- In general the equipment to perform cliché mounting is thought to be enough to perform the task well.
- Tape punching this was said to be working well but improvement suggestion would be punch templates including two templates, this would cut the time needed in half. Also suggestions on using other material to decrease the wear and tear inaccuracies of the punch templates. Risk for cuts on hand from punch templates.
- Taping is difficult and critical due to the risk of air bubbles and creases. Roller used for this works well for those who are trained. Differing opinions on the newly installed equipment.
- To have tape mounting as a separate procedure would be a good idea but would need a good routine.
- Sleeve washer for Twinlock works better than expected although working with Twinlock increases handling of sleeves.
- Sleeve storage

  - Sleeve storage was described as crappy. Mainly it was the working height that was the issue, since it is both too low and too high. Lower placed sleeves were thought to be more painful to take out because higher ones could be taken down gradually by using latter and thereby not bending on stretching, whereas the lower could not.
  - Latter used to take down sleeves from the sleeve storage was not very appreciated. Risk of losing balance when on latter holding sleeve.
  - Improvement suggestions either to increase the space for storage, reducing height, or the use of a paternosterverk.
- Microflex
  - Adding setting to the Microflex is thought to work well. If the wrong code is given it is usually possible to save at an early stage. In the case if a different size of sleeve is used it is possible it is damaged by the table etc.
  - Loading of sleeves onto the Microflex machine is not without problems. Some sleeves are very tough to push onto the shaft. 66 and 49 are the worst. 60 are newer and work better. Thought to be due to wear and tear. Sometimes this toughness leads to the sleeve bumping into the other end and damaged by the keyhole spike.
  - Previously poke yoke-commands were used for adjusting the table and stepping in the Microflex which was not preferred to one operator. It was mainly because it meant holding arms above shoulders a lot. The new way avoids this.

Trolleys

Horisontal trolley

- Easier to maneuver due to visibility ahead. Lowest middle position was particularly difficult. Recommendations for how a sleeve should be lifted from this position were received but impossible to follow.
- Sleeves and clichés are sometimes damaged when loaded onto the trolley. Marks are found in printing approximately twice a month.
- Limited number of trolleys available, therefore it is not a possibility to only use every other space on the trolley. This is only allowed for a certain size of sleeve (740).
- Improvement suggestions were either an adjustable height so that lifting could be done in a good working height, another was a revolving system.
- This trolley is preferred by at least one operator.

Vertical trolley

- This trolley is only used for sleeve sizes 49 and 51.
- An adjustment had been done to the trolleys that would prevent the possibility that the “driver” runs over his/her own foot.
- Lifting sleeves on and off this type of trolley means awkward lifting postures and is therefore not very favourable according to the operator. Lifting is additionally awkward since sleeves need to be lifted above the spear it is placed on top of.

- Visibility when maneuvering vertical trolley is bad according to some and good enough to others.

2.2. Lund Pre-press, Cliché Making

- Cliché making is usually ahead 48-72 hours with orders.
- Sorting was done in two main steps. First they were collected by visually determining designs, the operator would look at patterns and not décor numbers, placing similar designs together. Next step would be to look at each code and sort more thoroughly and colours in the right order.
- Productivity demands are more reasonable since the drying time was increased from 2,5h to 3h which automatically pulled down the productivity level.
- The plate is preferably carried folded when transported from CDI to processor. Risk for creating creases though, important to check for this before it is sent away.
- Before it is imaged it is quite stiff and easily breakable. Therefore it may not be carried in a folded manner, this means lifting above the shoulders for shorten than average people.
- Dryer
    - Need to pinch especially when carrying plate from processor to dryer which is felt in thumbs and grip at times. This due to the fear of dropping the slippery plate.

3. Additional interviews

3.1. Interview with two members of the WCM team, 26 November 2010

WCM work at Tetra Pak is based on the TPM methodology from Japan. This methodology has been adjusted to suit Tetra Pak. (Started TP 2003, the AA project??) WCM is a method/tool to use for the everyday work.

Pillars: It is important to have people with different background within these pillars when they are assembled. The pillars are supposed to collaborate with each other but they are concentrating on different losses. E.g. injuries, mishaps (tillbud), ergonomics.

Education when there is a new machine: The education is done by the suppliers or operators from another factory already using the new equipment. But it is the WCM people here that organises it.

Focus on losses: The work approach is to attack losses. The losses are identified through risk assessments done in the production, accidents, customer claims or retrieved data from for example P2 about for example short stops. These are then broken down to reasons and the biggest loss is focused on first.

Operator involvement: The goal is to have 100% operator involvement, but is depends on which team and what is done. Team with a clear task and goal and when it is something measureable is easier than when it concerns safety. (??) E.g. sleeve handling.

Ergonomic tools:

- It easily gets too cumbersome to use.
- Using trolleys for the cliché sheets would not work since it would be too crowded.
- The twinlock washer has been developed with continuous feedback from the operators.

SOPA and OPL are ways to standardise, e.g. that all operators should lift correctly and the same way. E&T pillars are responsible for educations and the one creating the OPL is responsible that it reaches everyone.

WCM teams:

- The members of the team depend on what is being solved.
- Kaizen
- ≈3±7

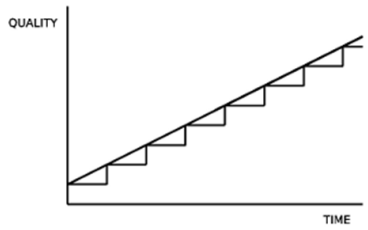
EM: The members of the team depend on what is being solved. E.g. EM project need someone from all pillars in the development work (?). This is to be able to implement the development in the production. X&Y express that they sometimes get machines with ergonomic issues to the production.

Ergonomic audits are done with OASEN (occupational health). The largest issue for pre-press is sleeve handling.

Steps when implementing new machine:

Hand on when the machine is installed. But installation plan, limited speed with lower efficiency for a while.

Kaizen: Kaizen team can also come with project solutions that give "jump". 7-7 team-form and then activities, e.g. to change 5S standard or maintenance change. This is smaller changes where teams are not needed. This work has given results: Spill has decreased from 10 to 5,5%. (Spill everything that is produced but that they cannot get paid for.) The operators also see these results.



Examples about trolleys:

- Horizontal sleeve trolley, based on the OASEN report. But, these trolleys are heavy and need force to start rolling and to stop.
- Developed layout for walk paths to avoid carrier traffic

- Decided that vertical sleeve trolleys can only be used for the lightest sleeves (49'' and 54'').

(Both trolleys are used when transporting an order to printing.)

Improve the WCM work: There is a **WCM organisation internally** at Tetra Pak. They come out and audit the pillars 4 times a year to make sure they are tackling the right issues and accidents. [This is done by group/operator presentations.] "The global WCM team" then assess the factory and gives a percent (Lund: 61%) based on an assessment sheet with scores.

GIPM assessments are also done (1st and 2nd assessment). Then members from Japan comes here to certify the factory on their methodology.

Good for a factory to have high marks since the factories compete among each other for the same orders.

Appendix 7
SHERPAs

Included SHERPAs are;

- Lund Pre-press
  - Cliché Making
  - Cliché Mounting
  - Cliché Mounting preparation
- Limburg Prepress
  - Cliché Making
- Easy ITS
  - Cliché Making & Mounting

Cliché Making Lund

1. Plan plate layout

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
1.1.1	S2, A6	Open wrong program	Cannot proceed	Immediate	L		Place only necessary icons on desktop
1.1.2	S2	Select unconfirmed or already started order	Cannot proceed	Immediate	M		Should not be possible (software barrier)
	S2	Omit to notice urgent order and select unprioritized	Urgent order delayed	None	M	!	Colour coding and arrange in order in table
	Latent	Pop-up causes action delay	Time-consuming and annoying	None	H	!	Investigate use of pop-ups, avoid linkage between all production process steps
	Latent	Select unprioritized order due to not reloaded inbox	Urgent order delayed	None	M	!	Continuous reloading
1.1.3	A8	Omit to print	Report missing when chosing which files to download	Task 1.2.4	L		Small issue since report needed for following tasks
1.2.1	S2, A6	Open wrong program	Cannot proceed	Immediate	L		Place only necessary icons on desktop
1.2.2	S2, A6	Open wrong program	Cannot proceed	Immediate	L		Place only necessary icons on desktop
1.2.3	S1,A8	Omit to download files	Cannot proceed	Immediate	L		P2 automatically connected to Merge
	A6	Download incorrect decór files	Confusion when planning layout	Task 1.2.4	L		P2 automatically connected to Merge
	A6	Download non-updated files	Risk that incorrect decór is printed	Task 1.2.4	M		Correct file versions should be supplied by digital files manager, older versions deleted
	Latent	Needed files not available	Cannot proceed	None	L		Correct file versions should be supplied by digital files manager, older versions deleted
1.2.4	A5	Image placed with large gaps	Inefficient use of plate	None	M		Lower than analogue process due to automatic distancing in Merge. Investigate predesigned common combinations of clichés.
	A5	Orders not produced together	Time-consuming in sorting after Cutting Table	None	L		Orders produced as collectively as possible minimize complexity and space requirements in Task 9
1.3.1	A7	Give file an inappropriate name, too similar to other orders	Risk for mixing up orders in cutting	Task 8	M		Standardized naming (order nr) or large engraving on cliché
1.3.2	I1	Omit to export	Cannot proceed	Task 3	M		Colour indication in P2/connected to changed status
1.3.3	A8	Omit to sign	Information might be lost	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
	A7	Sign with wrong number	Information might be lost	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
1.3.4	I1	Omit to change status	Risk that order is redone	Task 9.4	M		
	I2	Change to wrong status	Confusing in mounting prep	Task 9.4	M		Should not be possible (software barrier)
	A6, I2	Change wrong order	Risk that order is redone and difficulties for sorting to find order	Task 9.4	M		Investigate possibility to introduce software barrier making it impossible to start CDI if status not set to *processing,* and only possible statuses should be visible

Cliché Making Lund

2. Back Exposure							
Task step	**Error Mode**	**Error Description**	**Consequence**	**Recovery**	**P**	**C**	**Remedial Strategy**
2.1.1	C1	Omit to check back exposure is open	Time-consuming and additional risks	Immediate	M		Open with button or pedal
2.1.2	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	M		Slide plate over from pallet, pallet on appropriate height
	S2, A6	Retrieve already exposed plate	Plate overexposed	None	L		Clear storing system
	Latent	No plates in box	Cannot proceed	None	L		Storage near by
	A7	Walk into something with plate	Marks on plate	None	L		Slide plate over from pallet, pallet on appropriate height
2.1.3	A7	Break plate	Plate cracked or creased	None	M	!	Slide plate over from pallet, pallet on appropriate height
	Erg	Strain back while placing	Discomfort	None	M	!	Slide plate over from pallet, pallet on appropriate height
	A5	Fail to place within limits	Back exposure incomplete	None	L		Corner mark on exposure surface
2.1.4	A8	Omit to close	Cannot start machine	Task 2.2.2	L		Automatic closing connected to starting
	A9	Incomplete closing	Cannot start machine	Task 2.2.2	L		Close with button or pedal
	Erg	Strain back while closing	Discomfort	None	M		Close with button or pedal
2.2	A8	Omit to press button	Machine not started/Order delayed	Task 2.4	L		Feedback machine running, Automatic closing connected to starting
	A4	Fail to press button completely	Machine not started/Order delayed	Task 2.4	L		Feedback machine started and running
	A6	Press wrong button	Plate over exposed	None	L		Insert confirmation for changing exposure time
2.4	R1	Omit to detect that job is complete	Time-consuming	Task 3	L		Clear indication, for example exposure opens, small issue here since back exposing done separately
	R2	Mix up signals with other machine/job	Time-consuming	Immediate	L		Clear indication, for example exposure opens, small issue here since back exposing done separately
2.5.1	A2	Fail to wait	Plate underexposed	Immediate	L		Investigate if manual opening should be possible when running, small issue since job resumed when closed again
	Erg	Strain back while opening	Discomfort	None	L		Automatic opening when ready or use buttons or pedal to open
2.5.2	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	M	!	Slide plate over to pallet, pallet on appropriate height
	A7	Break plate	Plate cracked or creased	None	M		Slide plate over to pallet, pallet on appropriate height
2.5.3	S2	Place plate in wrong pile	Risk that plate is re-exposed	None	L		Clear storing system

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3. Imager							
Task step	**Error Mode**	**Error Description**	**Consequence**	**Recovery**	**P**	**C**	**Remedial Strategy**
3.1.1	C1	Omit to open cover	Time-consuming and additional risks	None	L		Open with button or pedal or leave open
	Erg	Strain back	Discomfort	None	M		Existing movable footstool improves working height
3.1.2	S2, A6	Retrieve unexposed plate	Plate destroyed	None	L		Clear storing system

	A7	Walk into something with plate	Marks on plate	None	M		Slide plate from exposure to imager
	A7	Break plate	Plate cracked or creased	None	M		Place machines in line
3.1.3	A3	Place plate up side down	Cannot proceed	Immediate	L		Make sure plastic cover upwards
	Erg	Strain back and/or shoulders	Discomfort	None	H	!	Existing movable footstool improves working height
3.1.4	A8	Omit to remove cover	Plate destroyed	Task 3.1.5.3	L		Small issue, but should be significant difference between plate with and without cover
3.1.5.1	A5	Edge placed asquint	Décor damaged	Task 3.1.5.2	L		Feedback when plate is correctly placed
3.1.5.2	A8	Omit to fasten edge	Plate not fastened	Task 3.1.5.3	L		Investigate automatic fastening
	A4	Do not fasten hard enough	Plate not fastened	None	L		Investigate automatic fastening
	A5	Edge fastened asquint	Décor damaged	Task 3.1.5.4	L		Investigate automatic fastening
3.1.5.3	Erg	Jam fingers in drum	Injury	None	L		Speed should be limited
	A3	Rotate wrong direction	Risk that plate creased	Immediate	L		Clear labelling next to buttons (loading/unloading) or lever instead of button
3.1.5.4	A8	Omit to fasten edge	Plate not fastened	None	L		Investigate automatic fastening
	A4	Do not fasten hard enough	Décor damaged	None	L		Investigate automatic fastening
	A5	Edge fastened asquint	Décor damaged	None	L		Investigate automatic fastening
3.1.6	A8	Omit to close cover	Cannot proceed	Immediate	M		Automatic closing connected to starting, today red indication on display of fail to close completly
3.2.1	A8	Omit to reposition laser	Cannot proceed	Immediate	M	!	Laser should reposition automatically
3.2.2	S1	Omit to select order	Cannot proceed	Immediate	L		Order selection and starting machine should be done with the same interface
	S2	Wrong order selected	Urgent order delayed	None	M		Usually named by the same operator, but if not communication is necessary. Good that orders removed from list when imaged
3.2.3	A8	Omit to press button	Machine not started/Order delayed	Task 3.4	L		Feedback machine running, Automatic closing connected to starting
	A4	Fail to press button completely	Machine not started/Order delayed	Task 3.4	L		Feedback machine started and running
3.4	R1	Omit to detect that job is complete	Time-consuming	Task 4	M		Distinctive indication on display, avoid sound since operators working close by
	R2	Mix up signals with other machine/job	Time-consuming	Immediate	L		Distinctive indication on display, avoid sound since operators working close by
3.5.1	A2	Fail to wait	Cannot proceed	Immediate	L		Manual opening is not possible when running
3.5.2.1	A8	Omit to loosen fastener	Cannot unload plate	Immediate	L		Investigate automatic unloading
	A4	Do not unscrew hard enough	Cannot unload plate	Immediate	L		Investigate automatic unloading
3.5.2.2	A8	Omit to place edge above imager	Plate damaged	Task 3.5.2.3	M		Investigate automatic unloading
3.5.2.3	Erg	Jam fingers in drum	Injury	None	L		Speed should be limited
	A3	Rotate wrong direction	Plate damaged	Immediate	L		Clear labelling next to buttons (loading/unloading) or lever instead of button
3.5.2.4	A8	Omit to loosen fastener	Cannot unload plate	Immediate	L		Investigate automatic unloading
	A4	Do not unscrew hard enough	Cannot unload plate	Immediate	L		Investigate automatic unloading
3.5.3	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	H	!	Sliding between imager and exposure should be further investigated
	A7	Touch décor when	Decór damaged	None	H	!	Unimaged edge around décor should be made

		lifting	(marks, scratches, dust)				sufficient
3.5.4	A8	Omit to close cover	Additional risks	None	L		Close with button or pedal or leave open

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4. Main Exposure

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
4.1.1	C1	Omit to check exposure is open	Time-consuming and additional risks	Immediate	M		Open with button or pedal or open automatically when ready
4.1.2	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	H	!	Sliding between imager and exposure should be further investigated
	A7	Walk into something with plate	Plate damaged (marks, scratches, dust)	None	M		Sliding between imager and exposure should be further investigated
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	H	!	Unimaged edge around décor should be made sufficient
4.1.3	A3	Place plate up side down	Plate destroyed	None	L		Sliding between imager and exposure should be further investigated
	C1	Omit to stretch out plate	Plate creased and damaged	None	L		Important to check
	Erg	Strain back while placing	Discomfort	None	H	!	Minimize plate handling
	A7	Break plate	Plate cracked or creased	None	M	!	Sliding between imager and exposure should be further investigated
4.1.4.1	A5	Place plate asquint	Holes punched asquint	Immediate	M		Possible to redo punching / Few operators find it an issue
	A7	Scratch plate when sliding	Plate damaged (marks, scratches, dust)	None	L		Keep exposure surface clean
	A3	Plate plate 90' wrong	Holes on wrong side	Task 5.1.3.2.4	L		Should not be possible to fit plate positioned the wrong way
	A4	Do not place plate fully inside puncher	Holes too far out	Task 5.1.3.2.4	M		Should be easy to push plate fully inside, holes can be redone
4.1.4.2	A4	Push pedal to loosely	Punching not complete	Immediate or Task 5.1.3.2.4	M		Newly installed puncher has minimized issue
	A8	Omit to remove punched out material	Risk for material in print	None	M		Newly installed puncher has minimized issue
	A9	Do not remove all punched put material	Risk for material in print	None	M		Newly installed puncher has minimized issue
4.1.4.3	A5	Place plate partly outside exposure area	Exposing incomplete	None	L		Edge in the back could improve positioning
4.1.5	A8	Omit to close	Cannot start machine	Task 4.2.2	L		Automatic closing connected to starting
	A9	Incomplete closing	Cannot start machine	Task 4.2.2	L		Automatic closing connected to starting
	Erg	Strain back while closing	Discomfort	None	M		Close with button or pedal or automatic closing
4.2	A4	Fail to press button completely	Machine not started/Order delayed	Task 4.4	L		Feedback machine started and running
	A8	Omit to press button	Machine not started/Order delayed	Task 4.4	L		Feedback machine running, Automatic closing connected to starting
	A6	Press wrong button	Plate under exposed	None	L		Insert confirmation for changing exposure time, not large issue since can just re-expose plate
4.4	R1	Omit to detect that job is complete	Time-consuming	Task 5	M		Clear indication, for example exposure opens
	R2	Mix up signals with other machine	Time-consuming	Immediate	L		Clear indication, for example exposure opens
4.5.1	A2	Fail to wait	Plate underexposed	Immediate	L		Investigate if manual opening should be possible when running, small issue since job resumed when closed again
	Erg	Strain back while opening	Discomfort	None	M		Automatic opening when ready or use buttons or pedal to open

4.5.2	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	H	!	Place machines in one line / investigate if possible to slide to processor
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	H	!	Unimaged edge arround décor should be made sufficient
	A7	Break plate	Plate cracked or creased	None	M	!	Sliding between exposure and processor should be further investigated

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5. Solvent Processor

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
5.1.1	C1	Omit to detect processor occupied	Plate might collide with previous plate	None	M	!	Plate should be moved directly when finished and released from fastener, barrier could be using only one fastener
5.1.2	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	H	!	Place machines in one line / investigate if possible to slide to processor
	A7	Walk into something with plate	Plate damaged (marks, scratches, dust)	None	M		Recommended to hold plate diagonally when carrying
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	H	!	Unimaged edge around décor should be made sufficient
5.1.3.1	A3	Place plate upside down	Plate destroyed	None	L		Should not be possible when carrying as recommended
	C1	Omit to stretch out plate	Plate damaged due to creases	Task 5.1.3.2.5	M		Automatic save when fastened or processor starts
	Erg	Strain back while placing	Discomfort	None	H	!	Place machines in one line / investigate if possible to slide to processor /position from side
	A3	Place plate 90' wrong	Cannot proceed	Task 5.1.3.2.4	L		Investigate if plate can be positioned from the side
5.1.3.2.1	Latent	Fail to find fastener	Cannot proceed	None	L		Investigate use of automatic clamp that automatically repositions / always fasten fastener on initial side after removing plate
5.1.3.2.2	A3	Place fastener wrong side up	Cannot proceed	Task 5.1.3.2.4	L		Investigate use of automatic clamp
	A8	Omit to fasten fastener	Cannot start machine	Task 5.2	L		Investigate use of automatic clamp
5.1.3.2.3	A7	Plate stuck to surface	Plate stretched and damaged	None	L		Processor table surface should be clean
	Erg	Strain when moving plate if sticking to surface	Discomfort	None	M		Processor table surface should be clean
5.1.3.2.4	S2, A6	Attach wrong plug to hole	Cannot proceed unless violation	Immediate	M		Investigate use of automatic clamp
5.1.3.2.5	A9	Omit to fasten one or more holes	Plate stretched and damaged	None	L		Investigate use of automatic clamp
	Erg	Strain back when trying to reach	Discomfort		H	!	Investigate use of automatic clamp
5.1.3.3	A8	Omit to move fastener	Cannot proceed	Task 5.2	L		Investigate use of automatic clamp that starts moving when start button pressed, today an alarm
	A9	Do not move fastener all the way up	Cannot proceed	Task 5.2	M		Investigate use of automatic clamp that starts moving when start button pressed, today an alarm
5.1.3.4	A9	Misplace report	Information might be lost	Task 8	L		Report system in computers linked to all machines
5.2	A8	Omit to press button	Machine not started/Order delayed	Task 5.4	L		Feedback machine started and running, today an alarm if not starting
	A4	Fail to press button completely	Machine not started/Order delayed	Task 5.4	L		Feedback machine started and running, today an alarm if not starting
5.3							

5.4	R1	Omit to detect that job is complete	Time-consuming	Task 6	L		Operators feel indication is sufficient
	R2	Mix up signals with other machine/	Time-consuming	Immediate	L		Operators feel indication is sufficient
5.5.1	A7	Stretch plate	Plate stretched and damaged	None	L		Investigate use of automatic clamp
5.5.2	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	H	!	Place machines in one line avoid slim passage between processor and dryers
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	H	!	Unimaged edge around décor should be made sufficient
	Erg	Fail to get a proper grip	Risk of dropping plate and discomfort in hands	None	H	!	Manual handling of slippery plates should be minimized
	Violation	Omit to use gloves	Physical contact with strong chemical	None	L		Manual handling of slippery plates should be minimized
5.5.3	A8	Omit to reposition fastener	Time consuming for new plate	None	M		Investigate use of automatic clamp that automatically repositions / always fasten fastener on initial side after removing plate

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6. Dryer

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
6.1.1	S2, A6	Open occupied drawer	Cannot proceed	Immediate	M		Operators preferred today's solution with whiteboards over displays close to each drawer, but place so that natural to walk past when loading
	C1	Omit to open drawer	Time-consuming and additional risks / Need help	None	M		Open with button or pedal
	Erg	Strain back when reaching or bending	Discomfort	None	M		Investigate more appropriate dryer design
	Latent	No vacant dryer drawers	Processor cannot be emptied or plate needs to be placed somewhere else	None	H	!	Extra table for back-up storage
6.1.2	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	H	!	Minimize plate handling
	A7	Walk into something with plate	Plate damaged (marks, scratches, dust)	None	H	!	Avoid slim passage between processor and dryers
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	H	!	Unimaged edge arround décor should be made sufficient
6.1.3	A3	Place plate up side down	Plate damaged due to risk for scratches	None	L		Should not be possible when carrying as recommended
	C1	Omit to stretch out plate	Plate damaged due to creases	None	H	!	Important to check cliché after positioning / harder to slide plate on drawer floors in old dryer (than new) due to dirt get stuck in air holes / Investigate possibilities to fully open drawer
	Erg	Fall over when leaning to place plate	Injury and damage on plate	None	L		Investigate more appropriate dryer design, especially avoid lowest drawers / harder to slide plate on drawer floors in old dryer (than new) due to dirt get stuck in air holes / Investigate possibilities to fully open drawer
	Erg	Strain back and shoulders while placing	Discomfort	None	H	! !	Investigate more appropriate dryer design, especially avoid lowest drawers / harder to slide plate on drawer floors in old dryer (than new) due to dirt get stuck in air holes / Investigate possibilities to fully open drawer

	A7	Stain décor when positioning	Fingerprints or scratches on plate	None	H	!	Unimaged edge arround décor should be sufficient, harder to slide plate on drawer floors in old dryer (than new) due to dirt get stuck in air holes (impossible to clean) and possibilities to fully open drawer
6.1.4	I2	Write information in wrong place	Information might be lost / Additional risks	Task 6.4.1	M		Operators preferred today's solution with whiteboards over displays close to each drawer, but place so that natural to walk past when loading
	I2	Write wrong time	Risk plate is removed at wrong time	Task 6.4.1	M		Operators preferred today's solution with whiteboards over displays close to each drawer, but place so that natural to walk past when loading
	I1	Omit to write information	Information be lost / Additional risks	Task 6.4.1	M		Operators preferred today's solution with whiteboards over displays close to each drawer, but place so that natural to walk past when loading
6.1.5	A4, A9	Leave drawer not fully closed	Drying incomplete (takes longer)	Task 6.4.1	M		Alarm if drawer open too long
	A8	Omit to close drawer	Drying incomplete (takes longer)	Task 6.4.1	L		Alarm if drawer open too long
	Erg	Jam fingers when pushing in drawer	Injury	None	L		Drawer should slide slowly
6.3	R1	Omit to detect that job is complete	Order delayed / Drawer occupied unnecessarily	Task 7	M		Operators preferred today's solution with whiteboards over displays close to each drawer
	R2	Mix up time on clock and board	Risk plate is removed at wrong time	Immediate	L		Operators preferred today's solution with whiteboards over displays close to each drawer
6.4.1	S2	Open drawer with wrong plate	Risk plate is removed at wrong time	Immediate	M		Operators preferred today's solution with whiteboards over displays close to each drawer
	S2	Open empty drawer	Cannot proceed	Immediate	L		Operators preferred today's solution with whiteboards over displays close to each drawer
6.4.2	A6	Remove wrong plate	Plate may not be dried	None	L		Operators should have sufficient knowledge of material to know if cliché is sufficiently dry / Operators preferred today's solution with whiteboards over displays close to each drawer
	A2	Remove plate too late	Order delayed / Drawer occupied unnecessarily	None	M		Cliché not damaged if removed too late / Operators preferred today's solution with whiteboards over displays close to each drawer
	A2/Violation	Remove plate too soon	Plate sticky and easily damaged	None	M	!	A standardized time should be set to avoid violations due to time pressure / Operators should have sufficient knowledge of material to know if cliché is sufficiently dry
	Erg	Strain back while removing	Discomfort	None	H	!	Investigate more appropriate dryer design that also allows opening the entire drawer
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	L		Smaller consequences in this step since plate dryed
6.4.3	A8	Omit to close drawer	Affects dryer capacity and increased risk for dust in machine	Immediate	L		Alarm if drawer open too long
	Erg	Strain back when bending	Discomfort	None	M		Investigate more appropriate dryer design
	A4	Fail to close drawer completely	Affects dryer capacity and increased risk for dust in machine	Immediate	M		Alarm if drawer open too long
	Erg	Jam fingers when pushing in drawer	Injury	None	L		Drawer should slide slowly
6.4.4	A8	Omit to erase time	Vacant drawer undetected (Risk that orders delayed)	None	M		Operators preferred today's solution with whiteboards over displays close to each drawer, but boards should be placed so that natural to walk past when loading
	A6	Erase wrong time	Information lost, risk plate is removed at wrong time	None	M		Operators preferred today's solution with whiteboards over displays close to each drawer, but boards should be placed so that natural to walk past when loading

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7. Light finishing

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
7.1.1	S2, A6	Open occupied drawer	Time-consuming and additional risks / Need help	None	L		Should not be possible to open drawer until job finished
	C1	Omit to open drawer	Time-consuming and additional risks / Need help	None	L		Open with button or pedal
	Latent	No vacant drawers	Dryer cannot be emptied or plate needs to be placed somewhere else	None	M	!	Extra table for back-up storage
7.1.2	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	H	!	Minimize plate handling, eg investigate possibility to include LF functionality in dryer
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	L		Smaller consequences in this step since plate dryed
7.1.3	A3	Place plate upside down	Plate damaged (marks, scratches, dust)	None	L		Should not be possible when carrying as recommended
	C1	Omit to stretch out plate	Plate damaged due to creases	None	M		Important to check cliché after positioning / harder to slide plate on drawer floors in old dryer (than new) due to dirt get stuck in air holes / Investigate possibilities to fully open drawer
	Erg	Strain back while placing	Discomfort	None	H	! !	Investigate more appropriate dryer design, Lf drawer too high on new machine, possible/necessary with movable footstool
	A7	Stain décor when positioning	Plate damaged (marks, scratches, dust)	None	L		Unimaged edge arround décor should be made sufficient / harder to slide plate on drawer floors in old dryer (than new) due to dirt get stuck in air holes / Investigate possibilities to fully open drawer
7.1.4	A4, A9	Leave drawer not fully closed	Lighting incomplete	Task 7.5.1	M		Alarm if drawer open too long
	A8	Omit to close drawer	Lighting incomplete	Task 7.5.1	L		Alarm if drawer open too long
	Erg	Jam fingers when pushing in drawer	Injury	None	L		Drawer should slide slowly
7.2.1	A8	Omit to push button	Machine not started/Order delayed	Task 7.4	L		Feedback that machine started and running /Investigate possibility to combine buttons in task 7.2.1 and 7.2.2
	A4	Fail to push button completely	Machine not started/Order delayed	Task 7.4	L		Feedback that machine started and running /Investigate possibility to combine buttons in task 7.2.1 and 7.2.3
7.2.2	A8	Omit to push button	Machine not started/Order delayed	Task 7.4	L		Feedback that machine started and running /Investigate possibility to combine buttons in task 7.2.1 and 7.2.4
	A4	Fail to push button completely	Machine not started/Order delayed	Task 7.4	L		Feedback that machine started and running /Investigate possibility to combine buttons in task 7.2.1 and 7.2.5
7.3							
7.4	R1	Omit to detect that job is complete	Order delayed / Drawer occupied unnecessarily	Task 8	M		Clear display with information on status (e.g. colour coding). Operators prefer not to increase auditive alarms
7.5.1	S2	Open drawer with wrong plate	Risk plate is removed at wrong time	Immediate	L		Mechanical barrier, make it impossible to open drawer until job finished
	S2	Open empty drawer	Cannot proceed	Immediate	L		Clear display with information on status (e.g. colour coding).

7.5.2	A2	Remove plate too late	Order delayed / Drawer occupied unnecessarily	None	M		Display with information about job clear (e.g. colour coding). Operators prefer not to increase auditive alarms
	A2/Violation	Remove plate too soon	Plate not completed	None	L		Mechanical barrier, make it impossible to open drawer until job finished
	Erg	Strain back when reaching to remove	Discomfort	None	H	!	Investigate more appropriate dryer design, Lf drawer too high on new machine
7.5.3	Erg	Jam fingers when pushing in drawer	Injury	None	L		Drawer should slide slowly
	A8	Omit to close drawer	Increased risk for dust in machine	Immediate	L		Alarm if drawer open too long
	A4	Fail to close drawer completely	Increased risk for dust in machine	Immediate	M		Alarm if drawer open too long

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8. Cutting table

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
8.1.1	Erg	Fail to adapt appropriate lifting posture	Discomfort	None	H	!	Investigate more appropriate dryer design, Lf drawer too high on new machine
	A7	Walk into something with plate	Plate damaged (marks, scratches, dust)	None	L		Place close to light finisher but still allow space around
	Erg	Stumble on foam carpet	Discomfort	None	L		Low carpet height around edges and ensure that carpet lite flat towards floor
8.1.2	Erg	Strain back when reaching with towel	Discomfort	None	M	!	Table height should be made appropriate to varying operators
	A9	Fail to remove all impurities from plate backside	Risk for short stops in printing	None	L		!!??
8.1.3	A3	Omit to turn over plate	Harder to see plate numbers -risk for cutting wrong or marks on decór	Task 8.2.1	L		Standardised procedure exists: Hold plate above edge of table and let go flat above table
	C1	Omit to stretch out plate	Risk cutting asquint	None	L		Low risk since plate hard
	Erg	Strain back while placing	Discomfort	None	M	!	Table height should be made appropriate to varying operators
	A5	Place plate wrong angle	Positioning dots can not be located	Task 8.2.2	M		Clear corner mark on surface or self adjusting cutter head
8.2.1	C1, R1	Omit to check engraved name on cliché	Risk that choose wrong order on computer	Immediate	L		Engraving on cliché needs to be properly visible
	S2	Select wrong order on computer	Cut décors incorrectly, plate destroyed	None	M		Standardized naming (order nr)
	S1	Omit to select order	Cannot proceed	Immediate	L		Machine and computer system could be coordinated to avoid having to use multiple interfaces
8.2.2	A5	Fail to position cutter head correctly	Décors cut incorrectly	None	M		Follow recommendation (QI-L061:19) / It should not be possible to start unless correctly positioned
8.2.3	A8	Omit to push start button	Machine not started	Task 8.4	L		Feedback that machine started and running
	A4	Fail to push button completely	Machine not started	Task 8.4	L		Feedback that machine started and running
8.3							
8.4	R1	Omit to detect that job is complete	Time-consuming	Task 9	M		Clear indication on machine interface (Since person most often is close by and in room, alarm can be discrete or only visual)
8.5.1	C1	Omit to reposition cutter head	Cannot proceed	Immediate	M		Functionality could possibly be included in the machine
8.5.2	A9	Forget one or more finished plates	Incomplete order	Task 9.2.3	L		Directly compare to checklist and count number of clichés cut per plate

8.5.3	A4	Dispose one or more finished plates	Incomplete order	None	L		Compare to checklist and count number of clichés cut per plate prior to disposing waste
	A9	Fail to remove dust and polymer waste from cutting table	Risk that polymer or dust get stuck on cliché	None	M		Clean surface to avoid dust (in Lund WCM nr 1536)

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9. Sort Cut Plates

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
9.1.1	A6	Add clichés belonging to another order in stack	Issues when mounting	Immediate	L		Engraving on cliché needs to be properly visible
9.1.2	Erg	Stand still for long periods of time	Discomfort	None	H	!	Rubber carpet is minimizing issue but job rotations or chairs and table for sorting could be a solution
		Misread décor number	Sorting may be incorrect	Mounting 1.3			Numbers on both clichés and manufacturing report need to have sufficient size
	A9	Omit to sort clichés	Time consuming in mounting, and higer risk that clichés are put in the wrong stack	Mounting 1.3	L		Investigate if sorting should be done as as single activity
	Erg	High elbows needed to separate sticky clichés	Discomfort in shoulders and arms	None	M	!	Investigate factors for minimizing stickiness of clichés and appropriate working height
9.1.3	A9	Omit to add clichés from order to stack	Issues when mounting	Task 9.2.3	L		Engraving on cliché needs to be properly visible
	Erg	High elbows needed to separate sticky clichés	Discomfort in shoulders and arms	None	M	!	Investigate factors for minimizing stickiness of clichés and appropriate working height
	A5	Place in wrong colour order	Time consuming in mounting	Mounting 1.3	M		
9.1.4	A8	Omit to place manufacturing order on top of stack	Information might be lost	Mounting 1.2	L		Produce information sheet example with what info should be in stack, place near by
	A7	Place manufacturing report on incorrect stack	Information might be lost and confusion in mounting	Mounting 1.2	L		Produce information sheet example with what info should be in stack, place near by
9.2.1	A8, C1	Omit to measure	Might affect print	Task 9.2.2	M		Include tick off on manufacturing report that thickness measured
	A6, C3	Measure wrong place	Might affect print	None	M		Standardized position, i.e. coordinates from corner and position cliché in "support" to do this
9.2.2	A8	Omit to sign	Information might be lost	Mounting 1.2	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
	A7	Sign with wrong number	Information might be lost	None/Mounting 1.2	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
9.2.3	A8, C1	Omit to count	Risk that wrong when in mounting	Mounting 1.3	L		Procedure to tick off when all clichés of one type has been collected facilitates this task
	R2	Count wrong	Issues when mounting	Mounting 1.3	L		Procedure to tick off when all clichés of one type has been collected facilitates this task
9.3	A8	Omit to add register plates	Time-consuming and risk for mounting error	Mounting 1.3	M		Smaller issue when register plate is made with order and included in stack (as opposed to QI-L062:9)
	A6	Add wrong sized register plates	Risk that mounted on wrong size which causes issues in printing	Mounting 1.3	M		Smaller issue when register plate is made with order and included in stack (as opposed to QI-L062:9)

	A8	Omit to write size on register plate	Risk that mounted on wrong size which causes issues in printing	None	M		Follow recommendation: (WCM nr 1366) Size written on register plates directly after cutting
9.4	A8, I1	Omit to change status	Order delayed	None	M	!	Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
	A7, I2	Change to wrong status	Order delayed	None	M	!	Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
9.5	A8	Omit to place stack on trolley	Hard to find, order might be delayed or confused with other orders	Immediate	L		Sufficient space in cliché making room
	A7	Place stack in wrong location	Hard to find, order might be delayed	Mounting 1.2	M		Shelves need to be clearly labelled

Cliché Mounting Lund

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
1.1	S2	Select unconfirmed or already started order	Cannot proceed	Immediate	L		Should not be possible (software barrier)
	Latent	Select unprioritized order due to not reloaded inbox	Urgent order delayed	None	M		Continuous reloading
	S2	Omit to notice urgent order and select unprioritized	Urgent order delayed	None	M		Colour coding and arrange in order in table, or have common window for the two printers
1.2	S2	Select incorrect pile of clichés	Decor numbers do not correspond to checklist	Immediate	L		Large tag of ordernr on top of pile
1.3	C1, Violation	Omit to double check sorting	Might miss previously done errors	Task 6.1	M	!	Minimize number of times sorting
1.4.1	R2	Find incorrect recipe	Table wrongly adjusted, risk that sleeve damaged	Immediate	L		Clarify parameters in table
1.4.2	A7	Type in wrong code	Table wrongly adjusted, risk that sleeve damaged	Immediate	M		Alternatives on buttons instead of using codes
	Erg	RSI in shoulders when working above shoulder height	Discomfort	None	M	!	Have become better with rubber spline installation but work above shoulder height should be avoided
1.5	C1, Violation	Omit to check	Time consuming and ergonomic risks	Task 2.3	L		Communication when order prepared
	Latent	Sleeves are not placed on nearby trolley	Order delayed due to waiting for sleeves	None	M		Need to plan the use of sleeves with regards to queues for both printers and enough sleeves have to be in system
2.1	A8	Fail to fully press open button	Cannot proceed	Immediate	L		Use pedal to be able to open when holding sleeve
	A8	Omit to open shaft end	Time consuming and ergonomic risks	Task 2.4	L		Use pedal to be able to open when holding sleeve
2.2	Erg	Strain in back when lifting	Discomfort	None	H	!	Redesign trolleys or lifting aid, lower placement particularly difficult
	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	H	!	Redesign trolleys or lifting aid
2.3	Erg	Strain in back and shoulders when pushing	Discomfort	None	H	!	Regularly maintain sleeves, worn out sleeves create more friction

	A4	Push too hard	Sleeve bump into key indicator on other side, damaged	None	M		Compressive end on machine
	A4	Push too loose	Sleeve not fully on shaft, cannot proceed	Immediate	M		Indication when in place
2.4.1	C1, Violation	Omit to check positioning of keyholes	Cannot proceed	Immediate	L		Indication when in place
	Latent	Fail to position correctly due to worn out keyholes	Sleeve might not be centred (affect print)	None	M	!	Facilitate sleeve loading by regular maintenance of sleeves and keyholes
2.4.2	A8, Violation	Hand not placed on sleeve	Sleeve might become uncentred	None	M		Follow recommendation (QI-L062:07)
2.5	A8	Fail to fully press close button	Cannot proceed	Immediate	L		Small issue due to air compression noisy
	A8	Omit to close shaft end	Cannot proceed	Immediate	L		Small issue due to air compression noisy
3.1	A7	Stretch or break tape due to stuck together in pile	Tape damaged/skew	None	M		Investigate how time affects stickyness in pile and alternatives to using punch templates
3.2.1	A5	Tape placed asquint	Risk that tape cannot be attached properly	Immediate	M		Semi-automatic taping
	A3	Place tape too much to the left or right	Risk that taping needs to be adjusted	Task 4.3.3	L		Use camera to position first tape piece (QI-L062:12)
3.2.2	A5	Tape placed asquint	Taping needs to be adjusted	Immediate	L		Use camera to position tape piece (QI-L062:12)
	A3	Place tape above or below edge	Tape gap may end up under decor and affect printing	Task 4.2.1	L		Use camera to position tape piece (QI-L062:12)
	A7	Tape stretched when placed	Risk for creased and damaged plate	None	M		Follow recommendation (QI-L062:12)
3.2.3	A4	Fail to hold out tape far enough	Risk for air bubbles	None	M	!	Follow recommendation (QI-L062:12)
	A4	Fail to hold out tape far enough	Risk for creases on tape	Immediate	M		Follow recommendation (QI-L062:12)
3.3.1	A4	Do not roll far enough	Risk that tape creases	Immediate	L		Follow recommendation (QI-L062:12)
	A8, Violation	Do not use roller to fasten edges	Risk for air bubbles	None	L		Follow recommendation (QI-L062:12)
	Latent	Roller with polymer or tape leftovers is used	Risk that leftovers transfered to cliché	None	L		Roller should be checked before usage (QI-L062:10)
	A6	Roller touches area with tape without cover	Dust and material from roller transferred to cliché	None	H	!	Investigate if rollers releasing less material can be used instead. Follow recommendation (QI-L062:10)
3.3.2	A8	Do not use roller	Risk for air bubbles	None	L		Follow recommendation (QI-L062:12)
	A4	Do not apply enough pressure	Risk for air bubbles	None	M		Follow recommendation (QI-L062:12)
	A5	Flattening of air bubbles causes tape to move	Risk that tape asquint	Immediate	M		Need to be focused and observant
3.3.3	A8	Fail to grab hold of plastic cover	Inefficient/Plastic cover not removed, cannot fasten cliché	Task 4.2.3	L		Follow recommendation (QI-L062:12)
3.3.4	A8	Fail to rotate sleeve	Cannot proceed	Immediate	L		Follow recommendation (QI-L062:12)
	A8	Do not manually adjust for possible skew edge of tape	Risk that tape cannot be attached properly	Immediate	M		Regularly control and replace skew punch templates (have become better)
	Erg	Stand with unevenly distributed load	Risk for RSI	None	H	!	Reduce pedal functions
3.4	A2	Press rubber spline by mistake	Risk for injury or damaged clichés	None	L		Investigate introducing protective barriers

4.1	Erg	Need to pull hard to separate clichés	Discomfort in shoulders	None	M		Investigate factors for minimizing stickiness of clichés
	Latent	Need to pull hard to separate clichés	Cliché decor may be damaged	None	M		Investigate factors for minimizing stickiness of clichés
	A7	Wrong cliché picked for certain sleeve	Wrong cliché mounted on sleeve	None	M	!	
4.2.1	A8, Violation	Do not use camera eye	Risk for incorrect mounting	None	L		Follow recommendation (QI-L062:13)
	A5	Microdot not fully centred	Risk that plate mounted asquint	None	M	!	Automated high precision mounting
4.2.2	A8, Violation	Do not use camera eye	Risk for incorrect mounting	None	L		Follow recommendation (QI-L062:13)
	A5	Microdot not fully centred vertically	Risk that plate mounted asquint	None	M	!	Automated high precision mounting
	A10, Violation	Readjust left microdot to adjust positioning	Risk that plate mounted asquint	None	L		Follow recommendation (QI-L062:13)
4.2.3	A4	Do not put enough pressure on microdot	Cliché might slide when fastening	Immediate	M		Follow recommendation (QI-L062:13)
4.2.4	A4	Do not put enough pressure on microdot	Cliché might slide when fastening	Immediate	M		Follow recommendation (QI-L062:13)
	A8, Violation	Omit to use roller	Cliché might slide when fastening	None	L		Follow recommendation (QI-L062:13)
4.3.1	A8, Violation	Omit to use roller	Cliché might slide due to unbalanced pressure	None	L		Follow recommendation (QI-L062:13)
	A4	Apply too little pressure on roller	Risk for air bubbles	None	L		Automatic pressure roller as with twinlock
4.3.2	A4	Apply too little pressure on roller	Risk for air bubbles	None	L		Automatic pressure roller as with twinlock
	A8, Violation	Omit to use roller	Risk for air bubbles	None	L		Follow recommendation (QI-L062:13)
	A4	Apply too much pressure	Tape may be damaged	None	L		Automatic pressure roller as with twinlock
4.3.3	A8	Fail to rotate sleeve	Cannot proceed	Immediate	L		Sufficient introduction to equipment should be given to operators
	Erg	Stand with unevenly distributed load	Risk for RSI	None	H	!	Varied tasks and positions alternatively reduced pedal functions
4.4	A2	Press rubber spline by mistake	Risk for injury or damaged clichés	None	L		Investigate introducing protective barriers
5.1.1	Latent	Fail to find masking tape	Cannot proceed	Immediate	L		Check needs to be done in previous steps
5.1.2	A8	Omit to fasten tape	Information lost	Task 6.2	L		Follow recommendation (QI-L062:10)
	I2	Fasten tape on wrong sleeve	Wrong information communicated	Task 6.2	L		Mounting operator writes order information on sleeeve when mounted
	A6	Fasten tape on wrong side	Confusion in printing/Time consuming	None or 7.4	L		Follow recommendation (QI-L062:10)
5.2.1	Latent	Fail to find slitting line	Cannot proceed	Immediate	L		Follow recommendation (QI-L062:23)
5.2.2	R2	Find incorrect recipe	Table wrongly adjusted, risk for mounting error	Immediate	L		Clarify parameters in table
	A7	Type in wrong code	Table wrongly adjusted, risk for mounting error	Immediate	M		Alternatives on buttons instead of using codes
	Erg	RSI in shoulders when working above shoulder height	Discomfort	None	M	!	Have become better with rubber spline installation but work above shoulder height should be avoided

5.2.3	A3	Slitting line placed on wrong side	Issues in printing	Task 6.1.4	L		Follow recommendation (QI-L062:23) Using Microflex recipe.
	A6	Slitting line placed on wrong sleeve	Slitting line missing on technical colour sleeve	None	M	!	Follow recommendation (QI-L062:23) Check for photocell on cliché.
	A4	Slitting line placed too close to clichés	Issues in printing	None	L		Follow recommendation (QI-L062:23) Using Microflex recipe.
	A4	Slitting line placed too far from clichés	Issues in printing	None	L		Follow recommendation (QI-L062:23) Using Microflex recipe.
5.2.4	A8	Fail to rotate sleeve	Cannot proceed	Immediate	L		Investigate alternative to using slitting line
	A5	Slitting line fastened asquint	Overlap or too much gap at other end	Immediate	H	!	Investigate alternative to using slitting line and only push down pedal half way to keep low speed
	A9	Slitting line edges not completely fastened	Needs to be re-fastened, otherwise issues in slitting	Immediate	M	!	Slitting line incorporated on a cliché
	Erg	Stand with unevenly distributed load	Risk for RSI	None	H	!	Varied tasks and positions alternatively reduced pedal functions
5.2.5	A4	Cut slitting line too short	Gap may cause ink in printing to loosen line from tape	Task 6.3.2	M		Cut out slitting lines in ACT in different lengths
	A4	Cut slitting line too long	Overlap may cause problems in printing	Task 6.3.2	M		Cut out slitting lines in ACT in different lengths
6.1.1	A8, Violation	Omit to check slitting line is mounted	Might miss previously done errors	None	M		Follow recommendation (QI-L062:23)
6.1.2	A8, Violation	Omit to check month year and lane marks	Might miss previously done errors	None	M		Follow recommendation (QI-L062:9)
6.2	A8	Omit to sign sleeve with employee and machine number	Possible problem in printing cannot be traced	None	M		Mounting operator writes order information on sleeeve when mounted
6.3.1	A8, Violation	Omit to check stepping	Might miss previously done errors	None	L		Follow recommendation (QI-L062:10)
6.3.2	A8, Violation	Omit to check for overlaps	Might miss previously done errors	None	M		Follow recommendation (QI-L062:10 and OPL 159)
6.3.3	A8, Violation	Omit to check cliché edge attachment	Ink might get in under cliché causing it to loosen	None	M		Follow recommendation (QI-L062:10)
6.4	A8, Violation	Omit to sign manufacturing report	Possible problem in printing cannot be traced to mounter	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
7.1	A8	Omit to open shaft end	Cannot proceed	Immediate	L		Place opening button close to shaft end
7.2	Erg	Strain in back and shoulders when pulling off	Discomfort	None	H	!	Air compression already used. Replacement or maintenance of worn out sleeves.
7.3	Erg	Strain in back when lifting	Discomfort	None	H	!	Use only horisontal trolleys and not too low or high
	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	M		Use only horisontal trolleys and not too low or high
	A7	Sleeve collides with other objects	Clichés scratched	None	H	!	Redesign trolley by reducing number of arms and ensure enough space between trolley and mounting machine, especially issue with large sleeves
7.4	A8	Omit to close shaft end	Cannot proceed	Immediate	L		Allow end to remain open until reloading
8.1	A8, I1	Omit to place manufacturing order in file folder	Information for follow ups lost	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.

8.2	A9, I3	Omit to sign something on checklist	Responsibility cannot be traced	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
	A8, I1	Omit to fill out order report	Information about order lost	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
8.3	A7, I1	Misplace order report	Information about order lost	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
8.4	A8, I1	Omit to place order on trolley	Information about order lost	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
8.5	A7, I2	Change to wrong status	Order delayed due to information not sent to printing	Immediate/None	M	!	Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
	A6, I2	Change wrong order	Confusion in printing/Order delayed due to information not sent to printing	Immediate/None	M		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
	A8, I1	Omit to change status	Order delayed due to information not sent to printing	Immediate/None	M		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.

Mounting Preparations Lund

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
1.1	S2	Select unconfirmed or already started order	Cannot proceed - Order not on shelf	Immediate	L		Should not be possible (software barrier)
	Latent	Select unprioritized order due to not reloaded inbox	Urgent order delayed	None	M		Continuous reloading
	S2	Omit to notice urgent order and select unprioritized	Urgent order delayed	None	M		Colour coding and arrange in order in table, should be easy to see list for both printers at the same time
	Latent	Select and start order that is not ready even if status says so	Cannot proceed	Immediate	M		Increase status alternatives in P2
	Latent	Pop-up causes action delay	Time-consuming and annoying	None	H	!	Investigate use of pop-ups and investigate if possible to avoid linkage between all production steps
1.2	A7	Fail to navigate in rotationg shelf system	Cannot proceed	Immediate	L		Instructions produced?
	Latent	Clichés are not in shelf even if status indicates it	Cannot proceed	Immediate	M		Increase status alternatives in P2
1.3	A8	Omit to collect customer folder	Information might not be sent to printing	Task Mounting 8.1	L		Follow recommendation (QI-L062:9)
	Latent	Fail to find customer folder	Information might not be sent to printing	Immediate	M		Suggestion to have a list next to customer folder shelf to indicate if folder is checked out or not
	S2, A6	Choose wrong folder	Information does not correspond to order	Immediate	L		Well organised customer archive facilitates. New system where folders are sorted by last number in ordernumber speeds up process and decreases work for customer archive manager.
2.1	I1	Omit to write checklist	Risk for errors when sorting	None	L		Mounting order could be pre-printed

	I2	Write wrong information on checklist	Higher risk of mounting wrong clichés	None	M	!	Mounting order could be pre-printed
2.2.1	A7	Place cliché in wrong pile	Higher risk of mounting wrong clichés	Task Mounting 1.3	L		Follow recommendation (QI-L062:9)
	A8	Omit to sort clichés into piles	Time-consuming and higher risk of mounting wrong clichés	Task Mounting 1.3	L		Follow recommendation (QI-L062:9) and minimize number of times sorting
	Erg	Need to pull hard to separate clichés	Discomfort in shoulders	None	M		Investigate factors for minimizing stickiness of clichés
	Latent	Need to pull hard to separate clichés	Cliché decor may be damaged	None	M		Investigate factors for minimizing stickiness of clichés
2.2.2	A8, Violation	Omit to use loupe	Might misread number and sort incorrectly	Task Mounting 1.3	M		Automatic marking in ACT (Loupe rarely used since it takes too long!)
	R2	Fail to detect that incorrect	Higher risk of mounting wrong clichés	Task Mounting 1.3	M	!	Minimize number of times sorting or introduce automatic counting /clarify amount on manufacturing report
2.2.3	A6	Place cliché in wrong order	Risk of mounting clichés in wrong order	Task Mounting 1.3	H	!	Minimize number of times sorting
	A8	Omit to sort clichés into order	Time-consuming and higher risk of mounting wrong clichés	Task Mounting 1.3	L		Minimize number of times sorting
2.2.4	A8, I1	Omit to write colour	Time-consuming and higher risk of mounting wrong clichés	Task Mounting 4	L		Automatic marking in ACT
	A7, I2	Write wrong colour	Higher risk of mounting wrong clichés	Task Mounting 4	L		Automatic marking in ACT
	A6, I2	Write colour on wrong cliché	Higher risk of mounting wrong clichés	Task Mounting 4	L		Automatic marking in ACT
2.3.1	A8, I1	Omit to cut off lane number	Information about décor lost	Task mounting 6.1.5	M		Investigate possibility to add this information already in imager
	A7, Violation	Use knife instead of tongs and slip when cutting off lane numbers	Cliché damaged	None	L		Follow recommendation (QI-L062:9)
	A7, Violation	Use knife instead of tongs and cut off lane numbers left on cliché	Risk for marks in printing	None	L		Follow recommendation (QI-L062:9)
	A7	Cut off lane numbers stuck on cliché	Risk for marks in printing	None	H	!	Investigate possibility to add this information already in imager
	A6, I2	Cut off lane numbers on wrong clichés	Information about décor lost	Task mounting 6.1.5	M	!	Investigate possibility to add this information already in imager
	A7, I2	Cut off wrong lane number	Information about décor lost	Task mounting 6.1.6	M	!	Investigate possibility to add this information already in imager
2.3.2	A8, I1	Omit to cut off month and year numbers	Information about décor lost	Task mounting 6.1.5	M		Investigate possibility to add this information already in imager
	A7, Violation	Use knife instead of tongs and slip when cutting off numbers	Cliché damaged	None	L		Follow recommendation (QI-L062:9)
	A7, Violation	Use knife instead of tongs and cut off numbers left on cliché	Risk for marks in printing	None	L		Follow recommendation (QI-L062:9)
	A9	Cut off numbers left on cliché	Risk for marks in printing	None	H	!	Investigate possibility to add this information already in imager

	A6, I2	Cut off month and year numbers on wrong clichés	Information about décor lost	Task mounting 6.1.5	M	!	Investigate possibility to add this information already in imager
	A7, I2	Cut off wrong month and year numbers	Information about décor lost	Task mounting 6.1.6	M	!	Investigate possibility to add this information already in imager
2.4.1	C1, Violation	Omit to check	Higher risk of mounting wrong clichés	Task Mounting 1.3	M		Minimize number of checks
	C2	Fail to detect previously made mistake	Might miss previously done errors	Task Mounting 1.3	M	!	Mounting order could be pre-printed
2.4.2.1	C1	Omit to check if register line not included	Risk that time-consuming in mounting	Task Mounting 1.3	L		Follow recommendation (QI-L062:23) OR incorporate register line in cliché
2.4.2.2	C1	Omit to check if register plates not included	Risk that time-consuming in mounting	Task Mounting 1.3	L		Register plates should be (and are) produced with an order (QI-L062:9)
3.1	S2	Select wrong sized punch template	Wrong sized tape in mounting	Task Mounting 3.2.1	L		Label with package type on punch templates
	Latent	Skew punch template used	Need to adjust when placing tape in mounting	Task Mounting 3.2.1	H	!	Regularly check quality of punch templates
3.2.1	A4	Pull out too little tape	Tape cannot be used/Material spill	None	M		Follow recommendation (OPL 217) or Automatic tape feeding and cutting after certain length
	A4	Pull out too much tape	Material spill increased	None	M		Follow recommendation (OPL 217) or Automatic tape feeding and cutting after certain length
3.2.2	A3	Do not center tape when positioning in pile	Risk for wrong sized tape piece	Task 3.2.5	M		Investigate alternatives to using punch templates
	A4	Place too many pieces in one pile before punching	Not possible to punch through pile	Task 3.2.2	L		Follow recommendation not to punch more than 5 layers of tape at a time (feedback interview)
3.2.3	A3	Cut off asquint	Risk for wrong sized tape piece	None	L		Should not be possible (machine barrier)
	A4	Cut off too short piece	Tape cannot be used/Material spill	None	L		Follow recommendation (OPL 217) or Automatic tape feeding and cutting after certain length
	A4	Cut off too long piece	Material spill increased	None	M		Follow recommendation (OPL 217) or Automatic tape feeding and cutting after certain length
3.2.4	A4	Fail to cut through all pieces	Necessary to punch again, risks for damaged edges	Immediate	L		Regularly check quality of punch templates and follow recommendations
	A3	Fail to punch centered	Wrong sized tape pile	Immediate	M		Investigate alternatives to using punch templates
	Latent	Tape skewed due to skewed template	Risk for issues in mounting	Task Mounting	M		Regularly control and replace skew punch templates (have become better)
3.2.5	Latent	Spill not together	Indication tape not correctly punched	Immediate	M		Follow recommendation not to punch more than 5 layers of tape at a time (feedback interview)
3.3	A3	Place tape up side down	Risk that tape quality decreased	None	L		The working procedure makes this error highly unlikely
4.1	Latent	Plate not available	Cannot proceed	Immediate	L		Follow recommendation (QI-L062:9) OR mounting operator writes order information on sleeeve when mounted
4.2	Latent	5 different colours not available	Colour system lost, violation necessary	Immediate	L		Follow recommendation (QI-L062:9) OR mounting operator writes order information on sleeeve when mounted
	A8	Omit one or more colours	Risk that information lost	Task Mounting 5.1.2	L		Follow recommendation (QI-L062:9) OR mounting operator writes order information on sleeeve when mounted

4.3	A7, I2	Write wrong numbers on tape	Risk that wrong information sent to printing	Task Mounting 5.1.2	L		Follow recommendation (QI-L062:9) OR mounting operator writes order information on sleeeve when mounted
	A6, I2	Write number on wrong tape	Risk that wrong information sent to printing	Task Mounting 5.1.2	L		Follow recommendation (QI-L062:9) OR mounting operator writes order information on sleeeve when mounted
	A8, I1	Omit to write information on tape	Time-consuming in mounting	Task Mounting 5.1.2	L		Follow recommendation (QI-L062:9) OR mounting operator writes order information on sleeeve when mounted
5.1	R2	Assume wrong sleeve type	Risk of collecting wrong sleeves	Task Mounting 1.5	L		Clear indication on manufacturing report
5.2.1	A7	Drop sleeve	Sleeve damaged	None	M	!	Sleeve storage better organised (e.g paternosterverk)
	Erg	Fall down from ladder	Injury	None	M	!	Sleeve storage better organised (e.g paternosterverk)
	Erg	Strain back when reaching	Discomfort	None	H	!	Sleeve storage better organised, now both too low and too high (e.g paternosterverk)
	A6, S2	Take down wrong sleeve	Time consuming and additional sleeve handling	Task Mounting 1.5	M		Sleeve storage better organised (e.g paternosterverk)
	A4	Take down too few sleeves for order	Time consuming and additional sleeve handling	Task Mounting 1.5	L		Clear indication on manufacturing report
	Latent	Correct sleeves not on shelf	Order delayed until available sleeves	None	H	!	Increase number of sleeves in production
5.2.2	Erg	Strain back when placing sleeve on trolley	Discomfort	None	M	!	Redesign trolley, largest issue with lowest one in the middle
	A4, Violation	Stack sleeves on top of eachother on trolley	Risk for accidents and damaged sleeves	None	L		Follow recommendation (OPL: WCM nr 778)
5.2.3	Erg	Run into someone with trolley	Injury	None	M		Ensure enough space and easily manouvred trolleys and alarm light (and OPL XXX)
	Erg	Run over own foot with trolley	Injury	None	M	!	Trolley should be pushed in front of operator / Smaller issue now when protection down to floor on trolley
	Erg	Hit by automatic carrier	Injury	None	M	!	Introduce route to storage not crossing carrier way (WCM project) and alarm light
	A7	Collide with other objects	Sleeves might be damaged	None	M		Ensure enough space and easily manouvred trolleys
5.3	A8	Omit to report used sleeves in computer	Confusion when looking for sleeve for other order OR when doing inventory	None	M		Investigate possibility to use barcode for easier registration
	A8	Omit to check keyhole status and sleeve state	Risk that mounting is incorrect	None	M		Regularly check quality of sleeves and keyholes
6.1	A8	Omit to sign report	Risk that errors cannot be traced	None	L		Follow recommendation (QI-L062:9)
6.2.1	A9	Everything not added to pile	Time-consuming in mounting	Task Mounting 1.3	M		Follow recommendation (QI-L062:9)
6.2.2	A7	Pile placed in wrong cabinet	Time-consuming in mounting since harder to find pile	Task Mounting 1.2	L		Large tag of ordernr on top of pile
6.2.3	A8, I1	Omit to write on whiteboard	Order harder to find and might be delayed	Task Mounting 1.2	L		Large tag of ordernr on top of pile
	I2	Write wrong order number	Order harder to find and might be delayed	Task Mounting 1.2	L		Large tag of ordernr on top of pile
6.3	I2	Change to wrong status	Order delayed due to information loss	None	M	!	Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
	I2	Change wrong order	Order delayed and confusion in mounting	None	M		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.

	A8, I1	Omit to change status	Order delayed due to information loss	None	M	!	Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
7.1	R2	Identify unfinished order as completed	Mounting operator cannot proceed if sleeve trolley removed	Immediate	L		Communication between operators
	R3	Do not realise order is ready	Crowded in mounting if sleeve trolley not removed	Immediate	L		Communication between operators
7.2	A7	Collide with other objects	Mounted sleeves might be damaged	None	M		Ensure enough space and easily manouvred trolleys
	Erg	Run into someone with trolley	Injury	None	M		Ensure enough space and easily manouvred trolleys and alarm light (and OPL XXX)
	Erg, Violation	Run over own foot with trolley	Injury	None	M	!	Trolley should be pushed in front of operator / Smaller issue now when protection down to floor on trolley
	Erg	Hit by automatic carrier	Injury	None	M	!	Introduce route to storage not crossing carrier way (WCM project) and alarm light

Cliché Making Limburg

2. Prepare order

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
2.1.1	S2, A6	Open wrong program	Cannot proceed	Immediate	L		Only necessary icons on desktop
2.1.2	S2	Select unconfirmed or already started order	Cannot proceed	Immediate	L		Should not be possible (software barrier)
	Latent	Select unprioritized order due to not reloaded inbox	Urgent order delayed	None	M	!	Continuous reloading
	S2	Omit to notice urgent order and select unprioritized	Urgent order delayed	None	M	!	Colour coding and arrange in order in table
2.1.3	A8	Omit to print	Cannot proceed	Immediate	M		Changing order status and printing should be connected
	A9	Only print order once	Issues when doing inventory	None	L		Default to print two copies
2.1.4	A8	Omit to put stamp on order	Issues later, information lost	Task 6	M		Information from stamp should be included in print out
2.1.5	I1	Omit to change status	Confusing, risk of restarting order	Task 10.8	M		Changing order status and printing should be connected
	I2	Change to wrong status	Confusing, risk of restarting order	Task 10.8	M		Changing order status and printing should be connected
2.2.1	I1	Omit to write order info	Harder to proceed	Immediate	L		Why need to write own? Useful list should be printed!
	I2	Write wrong order numbers	Risk of using wrong films	Task 10.4	M		Why need to write own? Useful list should be printed!
	I2	Write wrong quantity of film usage	Risk of using wrong films	Task 10.4	M		Why need to write own? Useful list should be printed!
2.2.2	A8	Omit to collect file	Cannot proceed	Immediate	L		Shelf with films should be placed close to exposure and working table
	A6	Collect wrong file	Risk of using wrong films	Task 2.2.4	L		Good labelling
	Latent	Cannot find file	Cannot proceed	Immediate	L		Good labelling / Possibility to quickly get new films
2.2.3	I1	Omit to write checklist	Harder to proceed, additional risks	Immediate	L		The information on print should be designed to be sufficient
	I2	Write wrong design number	Risk of using films wrong number of times	Task 4.1.3.1	M	!	Information on print should be designed to be sufficient

	I2	Write wrong number of times	Risk of using films wrong number of times	Task 10.4	M	!	Information on print should be designed to be sufficient
2.2.4	C1	Omit to check	Risk that wrong films used	Task 10.4	M		Check needed to make sure correct films used
	R2	Read incorrect design number	Wrong films used	Task 10.4	L		Design number on film should have sufficient size
2.2.5	A8	Omit to clean films	Risk for plate damage due to dust	None/Task 4.1.3.2	M		Procedure should be followed but ceiling needs to be improved
	A9	Do not clean all films	Risk for plate damage due to dust	None/Task 4.1.3.2	M		Procedure should be followed but ceiling needs to be improved
		Do not remove all dust	Risk for plate damage due to dust	None/Task 4.1.3.2	H	!	Procedure should be followed but ceiling needs to be improved

Cliché Making Limburg

3. Back Exposure

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
3.1.1	C1	Omit to check back exposure is open	Time-consuming and additional risks	Immediate	L		Already opens automatically in Limburg
3.1.2	Erg	Fail to adapt appropriate lifting posture	Discomfort	None	M		Slide plate over from pallet, pallet on appropriate height
	Latent	No plates in box	Cannot proceed	None	L		Storage near by
	A7	Walk into something with plate	Marks on plate	None	L		Slide plate over from pallet, pallet on appropriate height
3.1.3	A7	Break plate	Plate cracked or creased	None	M	!	Slide plate over from pallet, pallet on appropriate height
	Erg	Strain back while placing	Discomfort	None	M	!	Slide plate over from pallet, pallet on appropriate height
	A3	Fail to place within limits	Back exposure incomplete	None	L		Corner mark on exposure surface
3.1.4	A8	Omit to close	Cannot start machine	Task 2.2.2	L		Closing could be included in starting the machine
3.2.1	A8	Omit to press button	Cannot start machine	Immediate	L		Feedback machine started and running
	A4	Fail to press button completely	Cannot start machine	Immediate	L		Feedback machine running, Automatic closing connected to starting
	A6	Press wrong button	Plate over exposed	None	M		Clearly label each time alternative button
3.2.2	A8	Omit to press button	Machine not started/Order delayed	Task 3.4	L		Feedback machine running, Automatic closing connected to starting in Limburg which is a good indication
	A4	Fail to press button completely	Machine not started/Order delayed	Task 3.4	L		Feedback machine running, Automatic closing connected to starting in Limburg which is a good indication
3.3							
3.4	R1	Omit to detect that job is complete	Time-consuming	Task 4	L		Very low probability since operator waiting
	R2	Mix up signals with other machine/job	Time-consuming	Immediate	L		Very low probability since operator waiting

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4. Main Exposure

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy

4.1.1	A8	Omit to turn plate	Cannot proceed	Immediate	M	!	Since plastic cover will be removed this step cannot be omitted
4.1.2	A8	Omit to remove plastic cover	Plate destroyed	None	L		Useful if significant difference on plate with and without cover, e.g. colour
4.1.3.1	A5	Place films too close	Complications in cutting	None	M	!	Standard of not placing too many
	A5	Place films irregulary	Complications in cutting	None	M	!	Standard procedure exists: Recommendations on board on how to place films
	A9	Place too few films on plate	Inefficient and material spill	None	M	!	Standard to mix orders
	A5	Place films overlapping	Plate destroyed	None	M	!	Standard procedure exists: Recommendations on board on how to place films
	Erg	Strain back while placing	Discomfort	None	M	!	
	Erg	Need to bow to fit while placing	Discomfort	None	M	!	
4.1.3.2	A8	Omit to remove dust	Plate damaged due to dust	None	L		Ceiling and ventilation should minimize dust or digital process
	A9	Fail to remove all dust	Plate damaged due to dust	None	H	!	Ceiling and ventilation should minimize dust or digital process
	Erg	Strain back while reaching	Discomfort	None	M	!	
4.1.4.1	A8	Omit to roll over vacuum sheet	Risk that films move during exposure	Immediate	L		Suction to fixate films instead or digital process
	A9	Vacuum sheet not fully covering surface	Risk that films move during exposure	Immediate	L		Suction to fixate films instead or digital process
	Erg	Strain back while reaching	Discomfort	None	M	!	
4.1.4.2	A8	Omit to tape edges	Risk that films move during exposure	None	L		Suction to fixate films instead or digital process
	A9	Edges not fully taped	Risk that films move during exposure	None	L		Suction to fixate films instead or digital process
4.1.5	A8	Omit to close	Cannot start machine	Task 4.2.2	L		Closing could be included in starting the machine
4.2.1	A8	Omit to press button	Cannot start machine	Immediate	L		Feedback machine started and running
	A4	Fail to press button completely	Cannot start machine	Immediate	L		Feedback machine running, Automatic closing connected to starting
	A6	Press wrong button	Plate over exposed	None	M		Clearly label each time alternative button
4.2.2	A8	Omit to press button	Machine not started / Order delayed	Task 4.4	L		Feedback machine running, Automatic closing connected to starting
	A4	Fail to press button completely	Machine not started / Order delayed	Task 4.4	L		Feedback machine started and running
4.4	R1	Omit to detect that job is complete	Time-consuming	Task 5	L		Issue smaller than in Lund since exposure opens when finished (but larger than on BE since operator not waiting)
	R2	Mix up signals with other machine	Time-consuming	Immediate	L		Issue smaller than in Lund since exposure opens when finished (but larger than on BE since operator not waiting)
4.5.1	A8	Omit to remove tape	Cannot proceed	Immediate	L		Suction to fixate films instead or digital process
4.5.2	A8	Omit to roll back cover	Cannot proceed	Immediate	L		Suction to fixate films instead or digital process
4.5.3	A9	Do not collect all films	Films might get lost/Cannot proceed	None/Task 4.5.5	L		Easier to see films if look different from plate surface
	A9	Collect films but do not place in folder	Films might get lost	None	L		Films should always be kept in their folders
4.5.4	A3	Role together wrong way	Complications in puncher	Task 5	L		Small issue since recovered in puncher and plates have different width and length
	A8	Omit to role together	Other handling required	None	M		Small issue if forgets but will ease handling
4.5.5	Erg	Fail to adapt appropriate lifting posture	Discomfort	None	L		Lower issue since plate rolled together

	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	L		Lower issue since plate rolled together
	A7	Walk into something with plate	Plate damaged (marks, scratches, dust)	None	L		Lower issue since plate rolled together

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5. Punch holes

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
5.1	A3	Place wrong edge in puncher	Holes on wrong side, not possible to send through processor	Task 6.1.3.1.1	L		Not possible if plate correctly rolled together. Should not be possible to fit plate positioned the wrong way
	A4	Do not place plate fully inside puncher	Holes too far out	Task 6.1.3.1.1	M	!	Should be easy to push plate fully inside…
	A5	Place plate asquint	Holes punched asquint	Task 6.1.3.1.1	M	!	Should be easy to push plate fully inside
5.2	A9	Push pedal to loosely	Punching not complete	Immediate or Task 6.1.3.1.1	M	!	Puncher needs to be maintained to remain sharp
	A8	Omit to push pedal	No holes	Immediate	L		Step could be eliminated with another fastening system in processor
5.3	A8	Omit to remove punched out material	Risk for material in print	None	M		Highlight the importance to remove, could be avoided with clamp in processor instead or sharper puncher (as in Lund)
	A9	Do not remove all punched put material	Risk for material in print	None	H	!	Highlight the importance to remove, could be avoided with clamp in processor instead or sharper puncher (as in Lund)

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6. Processor

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
6.1.1	C1	Omit to check	Time consuming and additional risks	Immediate	M		Move plate directly when finished and releasing from fastener, only one fastener per machine and should not be possible to start machine until plate unloaded
6.1.2	Erg	Fail to adapt appropriate lifting posture	Discomfort	None	L		Issue smaller than in Lund due to in role and machines in line and very close
	A7	Walk into something with plate	Plate damaged (marks, scratches, dust)	None	L		Issue smaller than in Lund due to in role and machines in line and very close
6.1.3.1.1	S2, A6	Attach wrong plug to hole	Cannot proceed unless violation	Task 6.1.3.1.2	M		Investigate use of automatic clamp
6.1.3.1.2	A9	Omit to fasten one or more holes	Plate stretched and damaged	None	L		Investigate use of automatic clamp
	Erg	Strain back when trying to reach	Discomfort	None	L		Investigate use of automatic clamp
6.1.3.2	A7	Plate released carelessly	Plate scratched towards machine or floor	None	L		No sharp edges on machine and plate should be let go slowly. (In Lund procedure more careful)
6.1.4	A8	Omit to close cover	Cannot start machine	Task 6.2	L		Investigate if cover needed
	A9	Cover not fully closed	Cannot start machine	Task 6.2	L		Investigate if cover needed
6.1.5	I1	Omit to write	Information lost (errors harder to trace)	None	M		Information linked to computer system connected to all machines

	I2	Write wrong processor number	Information wrong (errors harder to trace)	None	L		Information linked to computer system connected to all machines
6.1.6	A9	Misplace report	Information lost (errors harder to trace)	Task 10	M		Information linked to computer system connected to all machines
6.2	A8	Omit to push start button	Machine not started / Order delayed	Task 6.4	L		Feedback machine started and running
	A4	Fail to push button completely	Machine not started / Order delayed	Task 6.4	L		Feedback machine started and running
6.4	R1	Omit to detect that job is complete	Time-consuming	Task 6.5.1	L		Small issue since alarm with sound and blinking light is located on top of each processor
	R2	Mix up signals with other machine	Time-consuming	Immediate	L		Small issue since alarm with sound and blinking light is located on top of each processor
		Turn off sound without unloading plate	Machine not emptied (Order delayed)	Immediate	M		Today the lamp continues to blink even without sound which is a good reminder (smaller issue than in Lund)
6.5.1 A	A8	Omit to place table	Risk for plate damage and ergonomic risks	Immediate	L		6.5.1-6.5.3 can be avoided if a static table is positioned directly after the processor and the plate is automatically placed on this table
	A4	Place table to far from machine	Risk of plate falling off table or need for unnecessary lifting	Immediate	M		6.5.1-6.5.3 can be avoided if a static table is positioned directly after the processor and the plate is automatically placed on this table
	A3	Place table to far to the right or left	Risk of plate falling off table	Immediate	M		6.5.1-6.5.3 can be avoided if a static table is positioned directly after the processor and the plate is automatically placed on this table
6.5.2 A	Erg	Strain back when reaching	Discomfort	None	H	!	In-built table positioned directly after the processor and the plate is automatically placed here (as in Lund)
	A7	Plate scratched towards machine	Plate scratched	None	H	!	In-built table positioned directly after the processor and the plate is automatically placed here (However, home-made Limburg solution has minimized this)
6.5.3 A	A8	Omit to detach plate	Cannot proceed	Immediate	L		Investigate use of automatic clamp
	A7	Stretch plate	Plate stretched and damaged	None	L		Investigate use of automatic clamp
6.5.4 A	A7	Accidentally cut décor	Part of plate décor destroyed	None	M		Sharp tools, possibly a knife better to remain stable and reach better
	Erg	Strain back when reaching	Discomfort	None	M	!	Sharp tools, knife with arm better to avoid posture
	A8	Omit to cut in halves	Harder handling in next steps	None	L		Standard procedure should preferably be followed to ease plate handling
6.5.1 B	A8	Omit to fasten fastener	Cannot proceed	Immediate	L		In-built table positioned directly after the processor and the plate is automatically placed here (as in Lund)
6.5.2 B	Erg	Strain back when reaching	Discomfort	None	M	!	In-built table positioned directly after the processor and the plate is automatically placed here (However, home-made Limburg solution has minimized this)
	A7	Plate scratched towards machine	Plate scratched	None	L		In-built table positioned directly after the processor and the plate is automatically placed here (However, home-made Limburg solution has minimized this)
6.5.3 B	A8	Omit to detach plate	Cannot proceed	Immediate	L		Investigate use of automatic clamp
	A7	Stretch plate	Plate stretched and damaged	None	L		Investigate use of automatic clamp
6.5.4 B	A7	Accidentally cut décor	Part of plate décor destroyed	None	M		Sharp tools, possibly the knife better to remain stable and reach better
	Erg	Strain back when reaching	Discomfort	None	M		Knife with arm has minimized issue
	A8	Omit to cut in halves	Harder handling in next steps	None	L		Standard procedure should preferably be followed to ease plate handling
6.5.5	Erg	Fail to adapt	Discomfort	None	L		Smaller issue with plate cut in halves

		appropriate lifting posture					
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	M	!	Spacious layout between processor and dryer (since critical moment) and unimaged edge around décor should be made sufficient
	A8	Omit to remove plate	Time-consuming and risks for dust	Immediate	L		Issue smaller than in Lund since more handling just done
6.5.6	A8	Omit to reposition fastener	Time consuming for new plate	Task 6.1.1	M		Investigate use of automatic clamp that automatically repositions / always fasten fastener on initial side after removing plate

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7. Dryer

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
7.1.1	S2, A6	Open occupied drawer	Time-consuming and additional risks / Need help	None	M		In Lund information on whiteboard, but no issue detected here and preference unknown
	C1	Omit to open drawer	Time-consuming and additional risks / Need help	None	M		Open with button or pedal
	Erg	Strain back when bending	Discomfort	None	M		Investigate more appropriate dryer design
	Latent	No vacant dryer drawers	Processor cannot be emptied or plate needs to be placed somewhere else	None	H	!	Extra table for back-up storage
7.1.2	Erg	Fail to adapt appropriate lifting posture	Discomfort	None	M		Avoid slim passage between processor and dryers (but smaller issue than in Lund due to plate in halves)
	A7	Walk into something with plate	Plate damaged (marks, scratches, dust)	None	M		Spacious layout that avoid operator meetings between processor and dryer, smaller issue than in Lund since in halves and short distance
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	M		Unimaged edge around décor should be made sufficient
7.1.3	A3	Place plate up side down	Plate damaged due to risk for scratches	None	L		Avoided when following standardised procedure
	C1	Omit to strech out plate	Plate damaged due to creases	None	M		Smaller issue than in Lund since plate in halves
	Erg	Strain back while placing	Discomfort	None	H	!	Investigate more appropriate dryer design, especially avoid lowest drawers / Investigate possibilities to fully open drawer / Smaller issue than in Lund since plate in halves
	A3	Place plate 90' wrong	Risk that inefficient and additional risks	Immediate	L		If both halves fit this is not an issue
	A7	Stain décor when positioning	Fingerprints or scratches on plate	None	M		Unimaged edge around décor should be sufficient but smaller issue than in Lund since plate in halves
7.1.4	A4, A9	Leave drawer not fully closed	Drying incomplete (takes longer)	Task 7.4.1	L		Alarm if drawer open too long
	A8	Omit to close drawer	Drying incomplete (takes longer)	Task 7.4.1	L		Alarm if drawer open too long
	Erg	Jam fingers when pushing in drawer	Injury	None	L		Drawer should slide slowly
7.3	R1	Omit to detect that job is complete	Order delayed	Task 8	M		In Lund information on whiteboard, but preference unknown in Limburg
7.4.1	S2	Open drawer with wrong plate	Risk plate is removed at wrong time	Immediate	L		In Lund information on whiteboard, but preference unknown in Limburg, but colour coding could make displays clearer
	S2	Open empty drawer	Cannot proceed	Immediate	L		In Lund information on whiteboard, but preference unknown in Limburg, but colour

							coding could make displays clearer
7.4.2	A6	Remove wrong plate	Plate may not be dried	Immediate?	L		In Lund information on whiteboard, but preference unknown in Limburg, but colour coding could make displays clearer
	A2	Removes plate too late	Order delayed	None	L		In Lund information on whiteboard, but preference unknown in Limburg, but colour coding could make displays clearer
	A2/Violation	Remove plate too soon	Plate sticky and easily damaged	None	M		A standardized time should be set to avoid violations due to time pressure / Operators should have sufficient knowledge of material to know if cliché is sufficiently dry
	Erg	Strain back while removing	Discomfort	None	M	!	Investigate more appropriate dryer design that also allows opening the entire drawer
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	L		Smaller consequences in this step since plate dried
7.4.3	A8	Omit to close drawer	Affects dryer capacity and increased risk for dust in machine	Immediate	L		Alarm if drawer open too long
	Erg	Strain back when bending	Discomfort	None	M		Investigate more appropriate dryer design
	A4	Fail to close drawer completely	Affects dryer capacity and increased risk for dust in machine	Immediate	M		Alarm if drawer open too long
	Erg	Jam fingers when pushing in drawer	Injury	None	L		Drawer should slide slowly

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8. Light finishing

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
8.1.1	S2, A6	Open occupied drawer	Time-consuming and additional risks / Need help	None	L		Should not be possible to open drawer until job finished
	C1	Omit to open drawer	Time-consuming and additional risks / Need help	None	L		Open with button or pedal
	Latent	No vacant drawers	Dryer cannot be emptied or plate needs to be placed somewhere else	None	M	!	Extra table for back-up storage
8.1.2	Erg	Fail to adapt appropriate lifting posture	Discomfort	None	H	!	Minimize plate handling, e.g. investigate possibility to include LF functionality in dryer, smaller issue than in Lund since plate in halves
	A7	Touch décor when lifting	Plate damaged (marks, scratches, dust)	None	L		Smaller consequences in this step since plate dryed
8.1.3	A3	Place plate up side down	Plate damaged due to risk for scratches	None	L		Should not be possible when carrying as recommended
	C1	Omit to stretch out plate	Plate damaged due to creases	None	M		Important to check cliché after positioning but height of LF inacceptable, smaller issue than in Lund since plate in halves
	Erg	Strain back while placing	Discomfort	None	H	!	Investigate more appropriate dryer design, LF drawer too high, possible with movable footstool
	A3	Place plate 90' wrong	Risk that inefficient and additional risks	Immediate	L		If both halves fit this is not an issue
	A7	Stain décor when positioning	Fingerprints or scratches on plate	None	M		Smaller consequences in this step since plate dried
8.1.4	A4, A9	Leave drawer not fully closed	Lighting incomplete	Task 8.5.1	M		Alarm if drawer open too long

	A8	Omit to close drawer	Lighting incomplete	Task 8.5.1	L		Alarm if drawer open too long
	Erg	Jam fingers when pushing in drawer	Injury	None	L		Slow sliding drawer
8.2.1	A8	Omit to push button	Machine not started/Order delayed	Task 7.4	L		Feedback that machine started and running /Investigate possibility to combine buttons in task 7.2.1 and 7.2.2
	A4	Fail to push button completely	Machine not started/Order delayed	Task 7.4	L		Feedback that machine started and running /Investigate possibility to combine buttons in task 7.2.1 and 7.2.3
8.2.2	A8	Omit to push button	Machine not started/Order delayed	Task 7.4	L		Feedback that machine started and running /Investigate possibility to combine buttons in task 7.2.1 and 7.2.4
	A4	Fail to push button completely	Machine not started/Order delayed	Task 7.4	L		Feedback that machine started and running /Investigate possibility to combine buttons in task 7.2.1 and 7.2.5
8.4	R1	Omit to detect that job is complete	Order delayed / Drawer occupied unnecessarily	Task 8	M		Clear display with information on status (e.g. colour coding). Operators prefer not to increase auditive alarms
8.5.1	S2	Open drawer with wrong plate	Risk plate is removed at wrong time	Immediate	L		Mechanical barrier, make it impossible to open drawer until job finished
	S2	Open empty drawer	Cannot proceed	Immediate	L		Clear display with information on status (e.g. colour coding).
8.5.2		Remove plate too late	Order delayed / Drawer occupied unnecessarily	None	M		Display with information about job clear (e.g. colour coding). Operators prefer not to increase auditive alarms
	A2/Violation	Remove plate too soon	Plate not completed	None	L		Mechanical barrier, make it impossible to open drawer until job finished
	Erg	Strain back when reaching to remove	Discomfort	None	M	!	Investigate more appropriate dryer design, LF drawer too high, possible with movable footstool
8.5.3	Erg	Jam fingers when pushing in drawer	Injury	None	L		Slow sliding drawer
	A8	Omit to close drawer	Increased risk for dust in machine	Immediate	L		Alarm if drawer open too long
	A4	Fail to close drawer completely	Increased risk for dust in machine	Immediate	M		Alarm if drawer open too long

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9. Cutting table

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
9.1	A7	Drop plates or walk into something	Plate damaged (marks, scratches, dust)	None	L		Spacious layout and avoid operators meeting
9.2	A5	Hold plate in wrong angle	Higher risk for cutting asquint or issues in mounting or printing	Immediate	M	!	Automatic cutting instead
9.3	A4	Leave too much frame around décor	Complications in mounting	Task Mounting 4.2.1	M	!	Automatic cutting instead
	A5	Cut in décor	Plate destroyed	None	M	!	Automatic cutting instead
	Latent	Remains built up on edge	Issues in printing	None	M		Sharp cutting blade, avoid material melting???
	Erg	Stand still for long periods of time	Discomfort	None	H	!	Rubber carpet is minimizing issue but job rotations or chairs and table for sorting could be solutions
	Erg	Stand still under ventilation drum	Discomfort in neck and shoulders due to draft	None	H	!	Avoid placing ventilation directly above working area
9.4	A4	Dispose one or more finished plates	Incomplete order	Task 10.4	L		Compare to checklist and count number of clichés cut per plate

	A9	Fail to remove dust and polymer waste from cutting table	Risk that polymer or dust get stuck on cliché	None	M		Clean surface to avoid dust (in Lund WCM nr 1536)

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10. Sort Cut Plates

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
10.1.1	A6	Add clichés belonging to another colour in stack	Issues when mounting	Task 10.4	L		Double check in task 10.4
	Erg	Stand still for long periods of time	Discomfort	None	H	!	Rubber carpet is minimizing issue but job rotations or chairs and table for sorting could be a solution
	A9	Omit to add clichés from colour to stack	Issues when mounting	Task 10.4	L		Double check in task 10.4
10.1.2	A5	Clichés are placed in wrong order	Issues when mounting	Mounting 1.6	M	!	Double check in task 10.4
	A5	The order is planned incorrectly with colours too separated	Uneven pressure causes issues in printing	Mounting 1.6	M	!	Standardized recommendation exists: Mix print with different colours on sleeve (in Lund WCM nr 218)
	Erg	Stand still for long periods of time	Discomfort	None	H	!	Rubber carpet is minimizing issue but job rotations or chairs and table for sorting could be a solution
	Erg	High elbows needed to separate sticky clichés	Discomfort in shoulders and arms	None	M	!	Investigate factors for minimizing stickiness of clichés and appropriate working height
10.2	A8, I1	Omit to cut off lane number	Information about décor lost	None	M		Double check in task 10.4, could this be included in imager?
	A6, I2	Cut off lane numbers on wrong clichés	Information about décor lost	None	L		Double check in task 10.4, could this be included in imager?
	A7, I2	Cut off wrong lane number	Information about décor lost	None	L		Double check in task 10.4, could this be included in imager?
	A7	Cut off number gets stuck to cliché	Number damages print	None	M	!	Standard working method in Lund (WCM nr 158): Use pincer instead of knife (catches cut off number and avoid damaging décor)
	A7	Scratches on cliché from cutting	Cliché damaged due to scratches	None	M	!	Standard working method in Lund (WCM nr 158): Use pincer instead of knife (catches cut off number and avoid damaging décor)
10.3	A8	Omit to cut off month and year numbers	Information about décor lost	None	M		Double check in task 10.4, could this be included in imager?
	A6	Cut off month and year numbers on wrong clichés	Information about décor lost/needs to be redone	None	L		Double check in task 10.4, could this be included in imager?
	A7	Cut off wrong month and year numbers	Information about décor lost	None	L		Double check in task 10.4, could this be included in imager?
	A7?	Cut off number gets stuck to cliché	Number damages print	None	M	!	Standard working method in Lund (WCM nr 158): Use pincer instead of knife (catches cut off number and avoid damaging décor)
	A7?	Scratches on cliché from cutting	Cliché damaged due to scratches	None	M	!	Standard working method in Lund (WCM nr 158): Use pincer instead of knife (catches cut off number and avoid damaging décor)
10.4	C1	Omit to check	Risk that sorting is wrong, lead to issues in mounting	Mounting	M	!	If errors have been done in a previous step this check is necessary
	C2	Make wrong check	Risk that sorting is wrong, lead to issues in mounting	Mounting	L		If errors have been done in a previous step this check is necessary
10.5.1	C1	Omit to check	Risk that not included, time-consuming in mounting	Mounting	L		Register lines and plates should be prepared and stocked in mounting too

10.5.2	A8	Omit to add register plates	Time-consuming and risk for mounting error	Mounting	M		Register lines and plates should be prepared and stocked in mounting too
	A6	Add wrong sized register plates	Risk that mounted on wrong size which causes issues in printing	Mounting	M		Register lines and plates should be prepared and stocked in mounting too
	A8	Omit to write size on register plate	Risk that mounted on wrong size which causes issues in printing	Mounting	M		Standardized recommendation exists: Size written on register plates directly after cutting (WCM nr 1366)
10.6	A8	Omit to put protective plastic	Clichés might stick together	None	L		Protective plastic makes handling in mounting easier but is not used in Lund
10.7	A8	Omit to detect issues	Risk for damaged print	None	M		In Lund all plates are controlled, could be a recommendation
10.8	A8, I1	Omit to change status	Order delayed	None	M		Manufacturing report connected to P2 so that needs to be properly filled out before changing status. (Sometimes paper preferred)
	A7,I2	Change to wrong status	Order delayed	Mounting	M		Manufacturing report connected to P2 so that needs to be properly filled out before changing status (Sometimes paper preferred)
10.9	A8	Omit to place stack on trolley	Hard to find, order might be delayed	Mounting 1.2	L		Stack should be placed as soon as finished

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1. Plan plate layout

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
1.1.1	S2, A6	Open wrong program	Cannot proceed	Immediate	L		Place only necessary icons on desktop
1.1.2	S2	Select unconfirmed or already started order	Cannot proceed	Immediate	M		Investigate possibility to introduce software barrier
	S2	Omit to notice urgent order and select unprioritized	Urgent order delayed	None	M	!	Colour coding and arrange in order in table / Investigate possibility to introduce software barrier
	Latent	Pop-up causes action delay	Time-consuming and annoying	None	H	!	Investigate use of pop-ups, avoid linkage between all production process steps
	Latent	Select unprioritized order due to not reloaded inbox	Urgent order delayed	None	M	!	Investigate possibility for continuous reloading
1.1.3	A8	Omit to print	Report missing when choosing which files to download	Task 1.2.3.1	L		Small issue since report needed for following tasks
1.2.1	S2, A6	Open wrong program	Cannot proceed	Immediate	L		Place only necessary icons on desktop
1.2.2	S2, A6	Open wrong program	Cannot proceed	Immediate	L		Place only necessary icons on desktop
1.2.3.1	A6	Download incorrect décor files	Confusion when planning layout	Task 1.2.4	M		P2 automatically connected to Merge / Improve visibility and readability of manufacturing order
	A6	Download non-updated files	Risk that incorrect décor is printed	Task 1.2.4	M		Correct file versions should be supplied by digital files manager, older versions deleted
	Latent	Needed files not available	Cannot proceed	None	L		Correct file versions should be supplied by digital files manager, older versions deleted
1.2.3.2	I2	Rip too many files	Material spill and increased risks when sorting	Task Sorting 4.3	L		P2 automatically connected to Merge / Improve visibility and readability of manufacturing order
	I2	Rip too few files	Increased risk in Sorting	Task Sorting 4.3	L		P2 automatically connected to Merge / Improve visibility and readability of manufacturing order

1.2.3.3	S1,A8	Omit to download files	Cannot proceed	Immediate	L		P2 automatically connected to Merge
1.2.4	A5	Décors placed leaving large empty area / large gaps	Inefficient use of plate	None	M		Lower than analogue process due to automatic distancing in Merge. Investigate predesigned common combinations of clichés.
	A5	Order not produced together	Time-consuming in sorting after Cutting Table	None	L		Orders produced as collectively as possible minimize complexity and space requirements in Sorting (Task 4)
	A9	Different formats not combined	Inefficient use of plate	None	L		Lower than analogue process due to automatic distancing in Merge. Investigate predesigned common combinations of clichés.
		Décors combined on plate rather than colours	Time-consuming in sorting after Cutting Table	None	M	!	Education and information necessary since new working procedure
1.3.1	A7, I3	Give file an inappropriate name, too similar to other orders	Risk for mixing up orders in cutting	Task 3.2.1	M		Standardized naming (order nr) or large engraving on cliché
1.3.2	I1	Omit to export plate layout to Imager and ACT	Cannot proceed	None	L		Investigate possibility of colour indication in P2, connected to changed status and it should be easy to retrieve file later
1.3.3	A8	Omit to sign manufacturing report	Information might be lost	None	M		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
	A7	Sign with wrong number	Information might be lost	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
1.3.4	A7	Place manufacturing report on incorrect place	Information might be lost	None or Task 4	L		Always place manufacturing report on specific location / Whiteboard in room for placing reports during production
1.3.5	I1	Omit to change status	Risk that order is redone	Task 4	M		Investigate possibility to introduce software barrier making it impossible to start CDI if status not set to *processing,* and only possible statuses should be visible
	I2	Change to wrong status	Difficulties for sorting to find order	Task 4	M		Investigate possibility to introduce software barrier making it impossible to start CDI if status not set to *processing,* and only possible statuses should be visible
	A6, I2	Change wrong order	Risk that order is redone and difficulties for sorting to find order	Task 4	M		Investigate possibility to introduce software barrier making it impossible to start CDI if status not set to *processing,* and only possible statuses should be visible

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2. Imager combi

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
2.1.1	Erg	Strain back and/or shoulders	Discomfort	None	M		Investigate possibility to slide plate over from pallet, pallet on appropriate height
	A7	Break plate when lifting	Plate cracked	None	M		Investigate possibility to slide plate over from pallet, pallet on appropriate height
2.1.2	A3	Place plate upside down	Cannot proceed	Immediate	L		Plastic cover indicates plate placed right way up
	A7	Break plate when placing on top of imager	Plate cracked	None	M		Investigate possibility to slide plate / Movable footstool improves working height / handles removed improves working height

	Erg	Strain back and/or shoulders	Discomfort	None	H	!	Investigate possibility to slide plate / Movable footstool improves working height / handles removed improves working height
2.1.3	A8	Omit to remove cover	Plate cannot be loaded	None	L		Small issue, but should be significant difference between plate with and without cover
2.1.4	A5	Edge placed asquint	Décor damaged or plate not loaded	None	L		Plate placed against edge indicating correct placement / Feedback when plate is correctly placed
	A4	Edge placed too far from opening	Plate cannot load	Immediate	L		Not large issue if plate is placed so that edge touches machine edge
2.2.1	S1	Omit to select order	Cannot proceed	Immediate	L		Order selection and starting machine would preferably be done using the same interface
	S2	Wrong order selected	Urgent order delayed /order redone	None	M		Standardized naming (order nr) or large engraving on cliché that can be compared to orders on computer / Good that orders are removed from list when used
2.2.2	A8	Omit to press button	Machine not started/Order delayed	Task 2.4	L		Feedback machine started and running
	A4	Fail to press button completely	Machine not started/Order delayed	Task 2.4	L		Feedback machine started and running
2.4	R1	Omit to detect that job is complete	Time-consuming	Task 3	L		Distinctive indication as table is automatically coming out, should be possibility to add sound depending on machine placements in factory
2.5.1	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	M	!	Investigate sliding solution between Imager combi and ACT or place close with appropriate directions. Smaller issue than pre-press since good table height
	A7	Touch décor when lifting	Décor damaged (marks, scratches, dust)	None	M		Unimaged edge around décor should be made sufficient for touching
2.5.2	Erg	Fail to adopt appropriate lifting posture	Discomfort	None	M	!	Investigate sliding solution between Imager combi and ACT or place close with appropriate directions. Smaller issue than pre-press since good table height
	A7	Walk into something with plate	Plate damaged (marks, scratches, dust)	None	M		Avoid slim passage between Imager combi and ACT and place with good directions
2.5.3	A8	Omit to reposition table	Additional risks	None	M		Should not be possible to start machine without repositioning table
	A2	Accidently push button to reposition table before plate retrieved	Risk that plate forgotten inside / Risk of collision inside machine	Task 3.1	M		Investigate possibility to include sensor on table

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3. Cutting Machine

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
3.1	A3	Omit to turn over plate	Difficult to see plate numbers, risk for cutting wrong or marks on decór	Immediate	L		Sliding would eliminate this risk
	C1	Omit to stretch out plate	Risk cutting asquint	None	L		Lower issue than in existing pre-press since harder plates in this step
	Erg	Strain back while placing plate on ACT	Discomfort	None	M	!	Table height should be made adjustable for all operators
	A5	Place plate wrong angle	Positioning dots cannot be located	Task 3.2.2	M		Clear corner mark on surface to facilitate placement OR self-adjusting cutter head
3.2.1	C1, R1	Omit to check name on plate	Risk of choosing wrong order on computer	Immediate	M		Information needs to be properly visible. Small issue since used in both previous steps.
	S2	Select wrong order on computer	Cut décors incorrectly, plate destroyed	None	M		Information needs to be properly visible. Small issue since used in both previous steps.

	S1	Omit to select order	Cannot proceed	Immedia te	L		Machine and computer system could be coordinated to avoid having to use multiple interfaces
3.2.2	A5	Fail to position cutter head correctly	Décors cut incorrectly	None	M	!	Follow recommendation (QI-L061:19) / It should not be possible to start unless correctly positioned. Possibly harder to see here since darker clichés
3.2.3	A8	Omit to push start button	Machine not started	Task 3.4	L		Feedback that machine started and running
	A4	Fail to push button completely	Machine not started	Task 3.4	L		Feedback that machine started and running
3.3							
3.4	R1	Omit to detect that job is complete	Time-consuming	Task 4	M		Should be possibility to add sound depending on machine placements in factory (probably close to sorting and then colour indication on display is sufficient)
3.5.1	C1	Omit to reposition cutter head	Cannot proceed	Immedia te	M		Investigate possibility to include functionality in machine
3.5.2	A9	Forget one or more finished plates	Incomplete order	Immedia te	L		Directly compare to checklist and count number of clichés cut per plate
3.5.3	A8, C1	Omit to check all cut plates from plate is in pile	Risk that cut plate is disposed	Task 6.2.2	M		Procedure to tick off when all clichés of one type has been collected could facilitate this task
	R2	Count wrong	Risk that cut plate is disposed	Task 6.2.2	L		Procedure to tick off when all clichés of one type has been collected could facilitate this task
3.5.4	A4	Dispose one or more finished plates	Incomplete order	None	L		Compare to checklist and count number of clichés cut per plate prior to disposing waste
	A9	Fail to remove dust and polymer waste from cutting table	Risk that polymer or dust get stuck on cliché	None	L		Small problem since plates will be cleaned in processor
3.5.5	A7	Place pile on top of another order	Could confuse sorting	Task 4.3	L		Working bench and light table with sufficient space

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4. Sorting

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
4.1	A9	Omit to retrieve manufacturing report	Cannot proceed	Immediate	L		Always place manufacturing report on specific location
	Latent	Cannot find manufacturing report	Time-consuming since new report has to be printed	Immediate	L		Always place manufacturing report on specific location
4.2	A8	Omit to collect customer folder	Information might not be sent to printing	Task 8.3.4	L		There should be no need for the folder in this step
	Latent	Fail to find customer folder	Information might not be sent to printing	Immediate	M		There should be no need for the folder in this step. Suggestion to have a list next to customer folder shelf to indicate if folder is checked out or not
	S2, A6	Choose wrong folder	Information does not correspond to order	Immediate	L		There should be no need for the folder in this step. Well organised customer archive facilitates. New system where folders are sorted by last number in ordernumber speeds up process and decreases work for customer archive manager.
4.3.1	A8	Omit to sort clichés into piles	Risk for mounting errors	Immediate	L		Structured sorting minimises sorting errors
	A7	Place cliché in wrong pile	Risk for mounting errors	Immediate	M	!	Structured sorting minimises sorting errors and should have sufficient space
	Erg	High elbows needed to separate sticky clichés	Discomfort in shoulders and arms	None	M	!	Work bench and light table should have adjustable height and investigate how to

							minimize stickiness
	Latent	Need to pull hard to separate clichés	Cliché decor may be damaged	None	M		Work bench and light table should have adjustable height and investigate how to minimize stickiness
	A9	Omit to add all clichés from order to stack	Risk for mounting errors	Task 6.2.2.1	M		Engraving on cliché needs to be properly visible, especially now when black, consider pen functionality in ACT
	Erg	Stand still for long periods of time	Discomfort	None	H	!	Rubber carpet, job rotations and adjustable tables with chairs
4.3.2	A8	Omit to sort clichés into order	Risk for mounting errors	Task 6.2.2.1	L		Structured sorting minimises sorting errors
	A7	Place clichés in wrong order	Risk for mounting errors	Task 6.2.2	M	!	Structured sorting minimises sorting errors
	Erg	High elbows needed to separate sticky clichés	Discomfort in shoulders and arms	None	M	!	Work bench and light table should have adjustable height and investigate how to minimize stickiness
	Latent	Need to pull hard to separate clichés	Cliché decor may be damaged	None	M		Work bench and light table should have adjustable height and investigate how to minimize stickiness
	Erg	Stand still for long periods of time	Discomfort	None	H	!	Rubber carpet, job rotations and adjustable tables with chairs
	A8	Miss to place technical colour clichés in lane order when single print			M	!	Education and information necessary since new step if marking included in CDI, consider adding pen functionality in ACT
4.3.3	A8	Omit to add blank plates	Risk for mounting errors	Task 6.2.2.3	M		Smaller issue when blank plate is made with order and included in stack (as opposed to QI-L062:9) but good to
	A6	Add wrong sized blank plates	Stop in mounting if not detected	Task 6.2.2.3 / Task 4.4	L		Smaller issue when blank plate is made with order and included in stack (as opposed to QI-L062:9). Follow recommendation: (WCM nr 1366) Size written on blank plates directly after cutting
	A6	Fail to find right sized blank plates	Stop in mounting if not detected	Immediate	L		Smaller issue when blank plate is made with order and included in stack (as opposed to QI-L062:9)
4.3.4	A8, I1	Omit to write information	Confusion when selecting 6 sub-piles to mount	Task 6.2.1	M		Education and information necessary since new working procedure
	A7, I2	Write wrong information on post-it	Confusion when selecting 6 sub-piles to mount	Task 6.2.1	M		Education and information necessary since new working procedure
4.4	A5	Place in wrong colour order	Risk for mounting error if not detected in check	Task 6.2.2.1	M	!	Important that order checked when selecting 6 sub-piles for mounting
	A5	Miss to place technical colour as top pile	Risk for mounting error if not detected in check	Task 6.2.2.1	L		Important that order checked when selecting 6 sub-piles for mounting
	A8	Miss to place register plate on top	Risk for mounting error if not detected in check	Task 6.2.2.1	L		Important that order checked when selecting 6 sub-piles for mounting
4.5.1	A8	Omit to sign manufacturing report	Information might be lost	Task 6.2.2	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
4.5.2	A8	Omit to place stack in rotating shelf	Hard to find, order might be delayed or confused with other orders	Task 6.1.3	L		Important to follow system
	A7	Place stack in wrong location	Hard to find, order might be delayed	Task 6.1.3	M	!	Shelves need to be clearly labelled
	A8	Omit to place manufacturing order on top of stack	Information might be lost	Task 6.1.3	L		Produce information sheet example with what info should be in stack, place near by
4.5.3	A7, I2	Change to wrong status	Order might be delayed due to no info in P2 for mounting	Immediate/ None	M	!	Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is

							sometimes preferable.
	A6, I2	Change wrong order	Order might be delayed due to no info in P2 for mounting	Immediate/ None	M		Should not be possible (software barrier) and only possible statused should be visible / P2 and manufacturing report connected
	A8, I1	Omit to change status	Order delayed due to information not sent to printing	Immediate/ None	M		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
4.5.4	A8	Omit to place			L		There should be no need for the folder in this step

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5. Semi Automatic Tape Mounting

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
5.1.1					H	!	Important to consider what to prioritise and to communicate!
5.1.2	C1,R2	Omit to check and assume wrong sleeve type	Risk of collecting wrong sleeves		L		Clear indication on manufacturing report
	Latent	Cannot find correct report	Time-consuming		M		Important to consider what to prioritise and to communicate!
5.1.3	A7	Fail to navigate in shelf	Cannot proceed	Immediate	L		Place clear instructions and labelling next to shelf
	Latent	Correct sleeves not on shelf	Order delayed until available sleeves	None	H	!	Increase number of sleeves in production
5.1.4	Erg	Strain in back when reaching	Discomfort	None	H	!	Recommended to use rotating shelf system to provide sleeves on good height
	Erg	Fall down from ladder	Injury	None	M	!	Recommended to use rotating shelf system to provide sleeves on good height
	A6, S2	Take down wrong sleeve	Time consuming and additional sleeve handling	Task Mounting 1.5	M		Sleeve storage better organised with good labelling (e.g paternosterverk)
	A4	Take down too few sleeves for order	Time consuming and additional sleeve handling	Task Mounting 1.5	L		Clear indication on manufacturing report
	A7	Drop sleeve due to bad gripping	Sleeve damaged /injury	None	M		Recommended to use rotating shelf system to provide sleeves on good height
5.1.5	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	H	!	Redesign trolleys or introduce lifting aid
	Erg	Strain back when placing sleeve on trolley	Discomfort	None	M	!	Redesign trolleys or introduce lifting aid, lower placement particularly difficult
5.1.6	A7	Collide with other objects	Sleeves might be damaged	None	L		Ensure enough space and easily manoeuvred trolleys
	Erg	Run into someone with trolley	Injury	None	M		Ensure enough space and easily manoeuvred trolleys and avoid crossing walk paths
	Erg	Run over own foot with trolley	Injury	None	M		Trolley should be pushed in front of operator and protection down to floor on trolley (as in Lund)
	Erg	Hit by automatic carrier	Injury	None	M	!	Route to storage should not cross carrier way
5.1.7	A8	Omit to report used sleeves in computer	Confusion when looking for sleeve for other order OR when doing inventory	None	M		Investigate possibility to use barcode for easier registration
	A8	Omit to check keyhole status and sleeve state	Risk that mounting is incorrect	None	M		Regularly check quality of sleeves and keyholes
5.2.1	Erg	Strain back while using force to wind lever	Discomfort	None	H	!	Investigate possibility to use motor, larger lever handle would decrease needed force

	Erg	Discomfort in hands when using force to wind lever	Discomfort	None	H	!	Investigate possibility to use motor, larger lever handle would decrease needed force
	A8	Omit to release shaft lever	Cannot proceed, sleeve not properly positioned	Immediate	L		Possibility to use motor is under investigation
5.2.2	A8	Omit to open shaft end	Cannot proceed	Immediate	L		Many steps needed to open end, investigate pushing button for automatic opening, alternatively a pedal
5.2.3	A8	Omit to turn on air compression	Ergonomic risks when trying to load sleeve	None	L		Investigate possibility to connect air compression to opening of shaft end as done in Microflex
5.2.4	Erg	Strain in back when lifting	Discomfort	None	H	!	Redesign trolleys, e.g. vertical instead or introduce lifting aid
	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	H	!	Redesign trolleys, e.g. vertical instead or introduce lifting aid
5.2.5	Erg	Strain in back and shoulders when pushing	Discomfort	None	H	!	Regularly maintain sleeves/check quality of sleeves, worn out sleeves create more friction
	A4	Push too hard	Sleeve bump into other side, damaged	None	L		Regularly maintain sleeves/check quality of sleeves, worn out sleeves create more friction
	A4	Push too loose	Sleeve not fully on shaft, cannot proceed	Immediate	L		Introduce feedback for when in place
5.2.6	A8	Omit to turn off air compression	Cannot proceed	Immediate	L		Investigate possibility to connect air compression to opening of shaft end
5.2.7	A8	Omit to close shaft end	Cannot proceed, sleeve not properly positioned	Immediate	L		Many steps needed to open end, investigate pushing button for automatic opening, alternatively a pedal
5.2.8	A8	Omit to release shaft lever	Cannot proceed, sleeve not properly positioned	Immediate	L		Larger lever handle would decrease needed force / Investigate possibility to use motor
	Erg	Strain back while using force to wind lever	Discomfort	None	H	!	Possibility to use motor is under investigation
	Erg	Discomfort in hands when using force to wind lever	Discomfort	None	H	!	Possibility to use motor is under investigation
5.3.1.1	A4	Fail to position tape roll correctly sideways	Taping needs to be redone	Immediate	M	!	Positioning block should be correct from beginning or easily adjustable, regular maintenance important
5.3.1.2	A7	Place ruler on unstretched tape	Creases on tape	Immediate	M		Investigate alternatives to using ruler or more automated machine
	A5	Place ruler misaligned	Difficulties when placing tape onto sleeve	Task 5.3.1.4	H	!	Investigate alternatives to using ruler or more automated machine
	Erg	WRULDs from standing leaned when working	Discomfort	None	H	!	Investigate possibility to redesign machine, e.g. decrease box
5.3.1.3	A8	Omit to position roll closer	Increased difficulties when placing tape onto sleeve	Immediate	L		Investigate alternatives to using ruler or more automated machine
5.3.1.4	A5	Attach ruler misaligned	Misaligned tape edge	Task 5.3.2.3	H	!	Investigate alternatives to using ruler or more automated machine
5.3.2.1	A8	Omit to position roller	Air bubbles not eliminated	None	L		Education and information necessary since new working procedure
5.3.2.2	A4	Press too long	Time-consuming and tape unused	Immediate	L		Stop (clicking) on machine to indicate where to stop rotating
	Erg	WRULDs from standing leaned when working	Discomfort	None	H	!	Investigate possibility to redesign machine, e.g. decrease box
5.3.2.3	A8, Violation	Omit to check	Difficulties with next row /Complications in printing	None	M	!	Introduce clear limits to misalignment, for example images of OK and NOT OK cases
	Violation	Let incorrect taping pass check	Difficulties with next row /Complications in printing	None	M	!	Introduce clear limits to misalignment, for example images of OK and NOT OK cases
5.3.3.1	A8	Omit to adjust roll out from sleeve	Cannot proceed, roll in the way	Immediate	L		Table with tape roll could possibly be made smaller so that operator can stand closer to sleeve
5.3.3.2	A5	Draw line asquint	Risk for cuts on sleeve surface	Immediate	M		Investigate alternatives to using ruler or more automated machine
	A3	Draw line outside ruler	Risk for cuts on sleeve	immediate	L		Investigate possibility to fix knife for

			surface				cutting along a fixed axis
	A8	Omit to draw line before cutting	Increased risk for gaps or overlaps	None	L		Investigate possibility to fix knife for cutting along a fixed axis
5.3.3.3	A5	Cut asquint	Increased risk for gaps or overlaps	None	H	!	Investigate possibility to fix knife for cutting along a fixed axis
	A5	Cut with incorrect angle	Gap or overlap on tape	None	H	!	Investigate possibility to fix knife for cutting along a fixed axis
5.3.4	Violation	Use knife to get hold of tape	Risk for cuts on sleeve surface	None	L		Introduce other, less sharp tool
5.3.5	A9	Fail to completely attach ends	Complications in printing / Ink may get in and tape loosen in printing	None	M		Use hand-roller for attaching ends
5.4.1	Erg	Strain back while using force to wind lever	Discomfort	None	H	!	Investigate possibility to use motor, larger lever handle would decrease needed force
	Erg	Discomfort in hands when using force to wind lever	Discomfort	None	H	!	Investigate possibility to use motor, larger lever handle would decrease needed force
	A8	Omit to release shaft lever	Cannot proceed, sleeve not properly positioned	Immediate	L		Possibility to use motor is under investigation
5.4.2	A9	Fail to open shaft end	Cannot proceed	Immediate	L		Many steps needed to open end, investigate pushing button for automatic opening, alternatively a pedal
5.4.3	A8	Omit to turn on air compression	Cannot proceed	Immediate	L		Investigate possibility to connect air compression to opening of shaft end
5.4.4	Erg	Strain in back and shoulders when pulling	Discomfort	None	M	!	Regularly maintain sleeves, worn out sleeves create more friction
	A2	Pull off sleeve too soon	Sleeve is suddenly released, high risk of injury	None	M	!	Education and information necessary since new working procedure
5.4.5	Erg	Strain in back when lifting	Discomfort	None	H	!	Redesign trolleys or lifting aid, lower placement particularly difficult
	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	H	!	Redesign trolleys or lifting aid
5.4.6	A8	Omit to turn on air compression	Ergonomic risks when trying to load sleeve	None	L		Investigate possibility to connect air compression to opening of shaft end as done in Microflex
5.4.7	A8	Omit to close shaft end	Cannot proceed, sleeve not properly positioned	Immediate	L		Many steps needed to open end, investigate pushing button for automatic opening, alternatively a pedal
5.4.8	A8	Omit to release shaft lever	Cannot proceed, sleeve not properly positioned	Immediate	L		Larger lever handle would decrease needed force / Investigate possibility to use motor
	Erg	Strain back while using force to wind lever	Discomfort	None	H	!	Possibility to use motor is under investigation
	Erg	Discomfort in hands when using force to wind lever	Discomfort	None	H	!	Possibility to use motor is under investigation

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6. Plate mounting

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
6.1.1	S2	Select unconfirmed or already started order	Cannot proceed	Immediate	L		Colour coding and arrange in order in table
	Latent	Select unprioritized order due to not reloaded inbox	Urgent order delayed	None	M		Investigate possibility for continuous reloading
	S2	Omit to notice urgent order and select unprioritized	Urgent order delayed	None	M		Colour coding and arrange in order in table
6.1.2	C1, Violation	Omit to check	Time consuming and additional ergonomic risks	None	L		Important to consider what to prioritise and to communicate!
	Latent	Sleeves are not taped and	Order very delayed due to	None	H	!	Important to consider what to prioritise

		placed on trolley	waiting for taping of sleeves				and to communicate!
	Latent	Wrong sleeves are taped and placed on trolley	Order very delayed due to waiting for taping of sleeves	None	M	!	Important to consider what to prioritise and to communicate!
	R1	Fail to detect that wrong sleeves taped and placed on trolley	Higher risk of mounting plates on wrong sleeves	Task 6.4.1.1	L		Important to consider what to prioritise and to communicate! Possible have sleeves with different colours.
6.1.3	S2	Select incorrect pile of clichés	Decor numbers do not correspond to checklist	Immediate	L		Large tag of ordernr on top of pile
6.2.1	S2	Select too many colours	Increased risk for mounting error	None/Immediate	L		Clear separation of sub-piles, e.g. with post-its
	S2, A9	Select too few colours	Inefficient use of mounting machine	None/Immediate	L		Clear separation of sub-piles, e.g. with post-its
	S2, A9	Fail to select all plates from one colour	Risk for mounting errors	Task 6.2.2	M	!	Clear separation of sub-piles, e.g. with post-its
6.2.2.1	C1, Violation	Omit to check	Higher risk of mounting errors	None	L		Procedure should be followed, therefore check must be performed / Education and information necessary since new working procedure
	C2	Fail to detect previously made mistakes	Mounting error	None	M	!	Visibility of manufacturing order and numbers on plates should improve results from checks
6.2.2.2	A9	All clichés not positioned in right direction	Clichés wrongly oriented on sleeve	None	M		Visibility of décors and numbers on plates should improve results from checks
6.2.2.3	C1	Omit to check if blank plates not included	Risk for mounting errors	None	M	!	Register plates should be (and are) produced with an order (QI-L062:9)
6.3.1	A9	Difficulties when opening	Additional risks	Immediate	L		Opening direction should be considered and height since no handle
6.3.2	A9	Difficulties when handling trolley	Additional risks	Immediate	L		Investigate if loading in trolley is the best method and if steering could be improved
6.3.3	S2, A6	Retrieve incorrect pile	Mounting error	None	L		Small issue if check and selection just done, Barcode on drawer with clichés, that may be scanned before entered into the machine, with information on sleeve size and plate size
6.3.4	A5	Fail to position correctly	Risk that plate cannot be lifted by machine	None	M		Need to be sufficient space in box / Information necessary since new working procedure
		Place pile upside down	Mounting error, Plates mounted wrong side up	None/Task 6.7	L		Unlikely since register plate should be on top. By checking number on top plate correct placing can be checked. Will probably be detected by camera when mounting and thus be saved
6.3.5.1	A8	Omit to adjust positioning toggles	Risk that plate cannot be lifted by machine	None/Task 6.7	M		Education and information necessary since new working procedure
	Latent	Fail to adjust positioning toggles	Risk that plate cannot be lifted by machine	None/Task 6.7	H	!	Positioning with toggles need to be investigated when larger register plate on top
6.3.5.2	A4	Fail to position trolley correctly	Cannot proceed	Immediate	L		Add sound indicator (click) that trolley is in place
6.3.6	A9	Omit to close door	Cannot proceed	Immediate	L		Add sound indicator that door is closed / Opening direction should be considered and height since no handle
		Fail to fully close door	Cannot proceed	Immediate	L		Add sound indicator that door is closed / Opening direction should be considered and height since no handle
6.4.1.1	S2	Select wrong sleeve batch	Mounting error	None / Task 6.6.2	L		Should be saved if correct size entered in settings and machine stops due to conflict / Different colours on sleeves / Good visibility on manufacturing report
	Latent	Batch of sleeves cannot be located	Cannot proceed	Immediate/ None	M		Important to consider what to prioritise and to communicate!

	S2	Select incomplete batch of sleeves	Difficulties to keep order together	Immediate	L		Important to consider what to prioritise and to communicate!
6.4.1.2	A7	Collide with other object	Mounted sleeves might be damaged	None	L		Ensure enough space, plan line from taped sleeves to mounting, and easily manoeuvred trolleys
	Erg	Run into someone with trolley	Injury	None	L		Ensure enough space, plan line from taped sleeves to mounting, and easily manoeuvred trolleys
6.4.2	A9	Difficulties when opening	Additional risks and irritation	Immediate	M	!	Unfolding of doors when opening should be done in one movement, through automatic opening or use other type of fence
6.4.3	A9	Pull out trolley skewly and get stuck	Time-consuming	Immediate	M		Precision required when handling mounter trolley, time to learn
6.4.4.1	Erg	Strain in back when lifting	Discomfort	None	H	!	Investigate possibility to replace vertical with mounting machine trolley after taping. Vertical trolley causes twisting.
	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	H	!	Investigate possibility to replace vertical with mounting machine trolley after taping. Vertical trolley causes twisting.
6.4.4.2	Erg	Strain in back when lifting	Discomfort	None	H	!	Investigate possibility to replace vertical with mounting machine trolley after taping. Vertical trolley causes twisting.
	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	M	!	Investigate possibility to replace vertical with mounting machine trolley after taping. Vertical trolley causes twisting.
6.4.5	A7	Scratch tape while trying to get a hold of cover	Airbubbles or uneven printing surface	None	M		Education and information necessary since new working procedure
	A9	Omit to remove all plastic covers	Plate will not get stuck to sleeve in mounting	None	L		Systematically working through each sleeves makes this a very unlikely issue
6.4.6	A9	Fail to position trolley completely	Trolley not locked in position /cannot proceed	Immediate	L		Precision required when handling mounter trolley, click to ensure correct placement
6.5	A8	Omit to close doors	Cannot proceed	Immediate	L		Not possible to start machine if not done
6.6.1	I2	Select incorrect plate size	Mounting error	Task 6.7	M		Machine should detect and warn when there is a conflict between loaded material and settings
6.6.2	I2	Select incorrect sleeve size	Mounting error	Task 6.7	M		Machine should detect and warn when there is a conflict between loaded material and settings
6.6.3	I2	Select incorrect number of sleeves	Mounting error	Task 6.7	L		Unlikely since information is visible and well represented on interface
6.6.4	I3	Omit to report deviations	One or more clichés mounted incorrectly	None	M	!	Large issue since mounting machine will finish job before it is noticed. All following plates may be misplaced / System where machine scans cliché and the placed correctly could be investigated.
	I2	Report incorrect deviation	One or more clichés mounted incorrectly	None	M	!	Large issue since mounting machine will finish job before it is noticed. All following plates may be misplaced / System where machine scans cliché and the placed correctly could be investigated.
6.6.5	A8	Omit to select start	Machine not started / Time-consuming	Task 6.8	L		Indication that machine is running (especially for bottle neck unit); E.g. blinking light, visible from main working area, Operators in Lund feel this solution is sufficient.
6.8	R1	Omit to detect that job is complete	Time-consuming	Task 7	M		Suggestion for indication; Blinking light, visible from main working area, for bottle neck unit. Operators in Lund feel this solution is sufficient.

	R2	Mix up signals with other machine	Time-consuming	Immediate	L		Suggestion for indication; Blinking light, visible from main working area, for bottle neck unit. Operators in Lund feel this solution is sufficient.
6.9.1	A9	Difficulties when opening	Additional risks	Immediate	L		Unfolding of doors when opening could be improved / Automatic opening when done could also be considered
6.9.2	A9	Pull out trolley skewly and get stuck	Time-consuming	Immediate	M		Precision required when handling mounter trolley, time to learn
6.9.3	A8	Omit to close plate mounter front doors	Additional risks	None	M		Safety procedure should be followed. However, if doors could be closed in one movement the risk for violations are decreased.
6.9.4	Erg	Strain in back when lifting	Discomfort	None	H	!	Investigate possibility to replace vertical with mounting machine trolley after taping. Vertical trolley causes twisting.
	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	M	!	Investigate possibility to replace vertical with mounting machine trolley after taping. Vertical trolley causes twisting.
6.9.5	Erg	Strain in back when lifting	Discomfort	None	H	!	Investigate possibility to replace vertical with mounting machine trolley after taping. Vertical trolley causes twisting.
	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	H	!	Investigate possibility to replace vertical with mounting machine trolley after taping. Vertical trolley causes twisting.
6.10	A7	Collide with other object	Sleeves and clichés might be damaged	None	M		Ensure enough space, plan line from moutning to processor, and easily manoeuvred trolleys
	Erg	Run into someone with trolley	Injury	None	L		Ensure enough space, plan line from moutning to processor, and easily manoeuvred trolleys
	Erg	Run over own foot with trolley	Injury	None	M		Trolley should be pushed in front of operator

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7. Solvent processor

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
7.1.1	R1	Omit to detect that sleeve can be loaded	Time-consuming	None	M	!	Clear indication on display or with light that new sleeve can be loaded, new procedure since loading and unloading not at the same time
7.1.2	A8	Omit to open processor front door	Time consuming and additional risks when loading sleeve	Task 7.1.3	L		Use button (or pedal) to be able to open while holding sleeve
	Erg	Reach when opening	Discomfort	None	M		Automatic opening with button (or pedal)
	Erg	Get door in head when opening	Discomfort	None	M		If automatic opening door could open in other angle
7.1.3	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	H	!	Redesign trolleys or lifting aid, e.g. possibility to elevate trolley, vertical trolley causes twisting
	Erg	Strain in back when lifting	Discomfort	None	H	!	Redesign trolleys or lifting aid, e.g. possibility to elevate trolley
7.1.4	Erg	Fail to adopt appropriate lifting posture due to high rest	Discomfort	None	H	!	Height of sleeve rest should be adjusted and lowered to minimise need to lift sleeve above elbow height.
	Erg	Need to hold sleeve far from body and tall operators need to bend	Discomfort	None	H	!	If door could be opened more taller operators could get closer to sleeve rest and would not have to bend

7.1.5	Erg	Strain back while reaching for door handle	Discomfort	None	M	!	Automatic opening with button (or pedal)
7.2.1	A7	Type in wrong settings	Clichés not correctly processed	None	L		Interface has good design but only possible options should be available
7.2.2	A8	Omit to press start	Machine not started/Order delayed	Task 7.4	L		Feedback machine started and running / Automatic closing connected to starting
	A4	Fail to press start button completly	Machine not started/Order delayed	Task 7.4	L		Feedback machine started and running / Automatic closing connected to starting
7.4	R1	Omit to detect that job is completed	Time-consuming	Task 8	M		Suggestion for indication; Blinking light, visible from main working area. Operators in Lund feel this solution is sufficient. Should be possibility to add sound depending on machine placements in factory
	R2	Mix up signals with other machine	Time-consuming	Immediate	L		Suggestion for indication; Blinking light, visible from main working area. Operators in Lund feel this solution is sufficient. Should be possibility to add sound depending on machine placements in factory
7.5.1	Erg	Reach when opening	Discomfort	None	L		Automatic opening with button (or pedal)
7.5.2	Erg	Fail to adopt appropriate lifting posture due to low rest	Discomfort	None	M	!	If possible sleeve rest should be slightly higher
7.5.3	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	H	!	Redesign trolleys or lifting aid, e.g. possibility to elevate trolley, vertical trolley causes twisting
	Erg	Strain in back when lifting	Discomfort	None	H	!	Redesign trolleys or lifting aid, e.g. possibility to elevate trolley
	A7	Sleeve collides with other objects	Clichés scratched	None	M		Make sure there are not too many arms on trolley, and ensure enough space between trolley and processor machine, especially issue with large sleeves
7.5.4	Erg	Strain back while reaching for door handle	Discomfort	None	M	!	Investigate possibility to automate closing and opening of processor doors. Alternatively a handle that is placed so that easier to reach OR Use pedal to be open and close door.

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8. Finalize order

Task step	Error Mode	Error Description	Consequence	Recovery	P	C	Remedial Strategy
8.1	S2	Retrieve incomplete order	Order not kept together, sleeve missing in printing	Task 8.2.5	L		Important to communicate between process steps
	A7	Collide with other objects	Sleeves and clichés might be damaged	None	L		Ensure enough space, plan line from processor to QC, and easily manoeuvred trolleys
	Erg	Run into someone with trolley	Injury	None	L		Ensure enough space, plan line from processor to QC, and easily manoeuvred trolleys
	Erg	Run over own foot with trolley	Injury	None	M		Trolley should be pushed in front of operator
8.2.1	Erg	Strain in back and shoulders when pushing	Discomfort	None	H	!	Regularly maintain sleeves/check quality of sleeves, worn out sleeves create more friction, air compression needed?
	A4	Push too hard	Sleeve bump into other side, damaged	None	L		Compressible material on machine
	A4	Push too loose	Sleeve not fully on shaft / cannot proceed	Immediate	L		Add sound indicator (e.g. click) that sleeve is in place

	A9	Fail to position sleeve correctly	Risk for incorrect measurements	Immediate	M		Add sound indicator (e.g. click) that sleeve is in place
8.2.2.1	C1, Violation	Omit to check that register plate is mounted	Might miss previously done errors	None	M		Task should be included on checklist on manufacturing report
8.2.2.2	C1, Violation	Omit to check month year and lane marks	Might miss previously done errors	None	M		Task should be included on checklist on manufacturing report
8.2.2.3	C1, Violation	Omit to check stepping	Might miss previously done errors	None	L		Task should be included on checklist on manufacturing report
8.2.2.4	C1, Violation	Omit to check for overlaps	Might miss previously done errors	None	L		Task should be included on checklist on manufacturing report
8.2.2.5	C1, Violation	Omit to check cliché edge attachment	Ink might get in under cliché causing it to loosen	None	L		Task should be included on checklist on manufacturing report
8.2.3		This task is not covered in the analysis					
8.2.4.1	A7, I2	Write wrong numbers on tape	Wrong information sent to printing	None	L		Information about procedure and should be part of recommended process
	A6, I2	Write number on wrong tape	Wrong information sent to printing	None	L		Information about procedure and should be part of recommended process
	A8, I1	Omit to write information on tape	Cannot proceed	Immediate	L		Information about procedure and should be part of recommended process
8.2.4.2	A8	Omit to sign sleeve with employee and machine number	Possible problem in printing cannot be traced	None	L		Good that writing information and signing is one task now
	A6, I2	Write incorrect information on tape	Risk that wrong information sent to printing		L		Printing operators should compare information on sleeve to information on production order
8.2.5	A7	Place sleeve on wrong trolley	Risk that order is not kept together, issues in printing	Task 8.3.3	L		Finished orders should be removed from pre-press area
	Erg	Strain in back when lifting	Discomfort	None	H	!	Make sure trolleys are not too low or high
	Erg	Strain wrists or hands due to twisting when lifting	Discomfort	None	H	!	Use only horizontal trolleys and not too low or high
	A7	Sleeve collides with other objects	Clichés scratched	None	M		Make sure there are not too many arms on trolley, especially issue with large sleeves
8.3.1	A8, Violation	Omit to sign manufacturing report	Possible problem in printing cannot be traced to mounter	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
8.3.2	A8, I1	Omit to place manufacturing order in folder	Information for follow ups lost	None	L		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
8.3.3	A9, I3	Omit to sign something on checklist	Responsibility cannot be traced	None	L		Should not be an issue since the same procedure is used and is working today
	A8, I1	Omit to fill out delivery report	Information about order lost	None	L		Should not be an issue since the same procedure is used and is working today
8.3.4	A7, I1	Misplace delivery report	Information about order lost	None	L		Should be part of recommended procedure and there should be a pocket on trolley
8.3.5	A8, I1	Omit to place folder on trolley	Information about order lost	None	L		Should be part of recommended procedure and there should be a pocket on trolley
8.3.6	A7, I2	Change to wrong status	Order delayed due to information not sent to printing	Immediate/None	M	!	Only possible statuses should be available. Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
	A6, I2	Change wrong order	Confusion in printing/Order delayed due to information not sent to printing	Immediate/None	M		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.

	A8, I1	Omit to change status	Order delayed due to information not sent to printing	Immediate/None	M		Manufacturing report could be connected to P2 and requiring information before status may be altered. Note: Information on paper is sometimes preferable.
8.4	A7	Collide with other objects	Sleeves might be damaged	None	M		Ensure enough space and easily manoeuvred trolleys
	Erg	Run into someone with trolley	Injury	None	M		Ensure enough space and easily manoeuvred trolleys and avoid crossing walk paths
	Erg	Run over own foot with trolley	Injury	None	M		Trolley should be pushed in front of operator and protection down to floor on trolley (as in Lund)
	Erg	Hit by automatic carrier	Injury	None	M	!	Route to storage should not cross carrier way